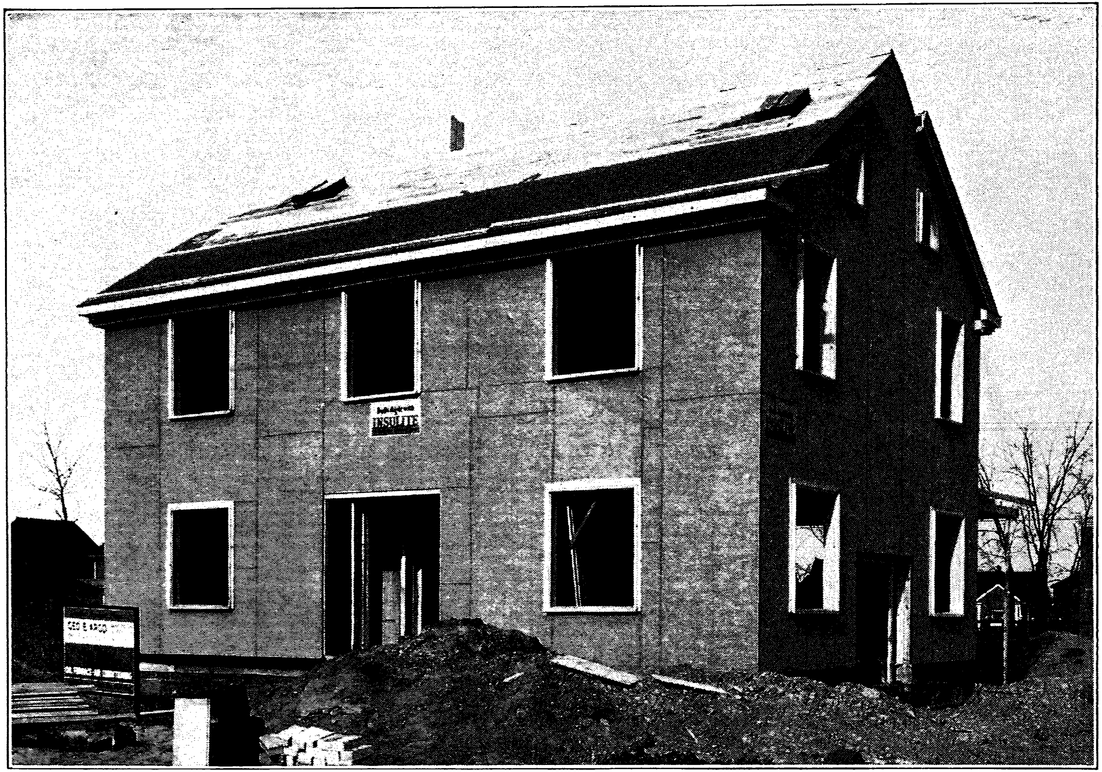

HOUSE SHEATHED WITH RIGID INSULATION

Courtesy of The Insulite Company, Minneapolis, Minnesota

HEATING AND VENTILATING

AIR CONDITIONING

A Home-Study Course and General Reference Work on the Principles, Design, Selection, and Application of Heating and Air-Conditioning Appliances and Systems for Residential, Commercial, Industrial Use.

Illustrated

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Courtesy of The Insulite Company, Minneapolis, Minnesota

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THE EDITORS *have consulted standard technical literature and expert engineers in the preparation of these volumes. They desire to express their indebtedness particularly to the following authorities and organizations:*

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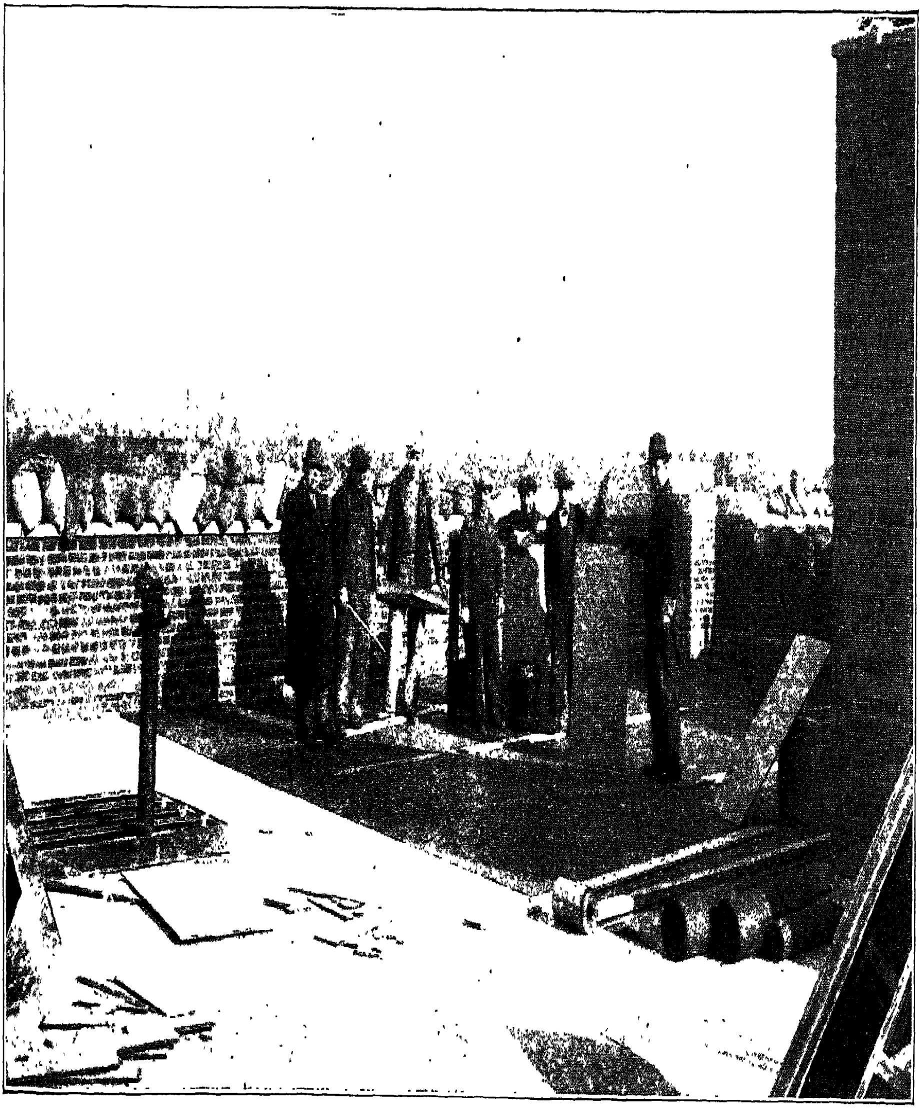

ROOF INSULATION

Courtesy of Insulite Company

FOREWORD

★AIR CONDITIONING is not a new idea. As early as 1911 Willis H. Carrier had formulated some of the principles and laws which are being used in present day air-conditioning engineering. However, he probably did not dream of the possibilities in the field to which he contributed.

★At first, air conditioning was developed only for use in factories where the control of humidity and where summer cooling permitted the continuation of processes previously confined to the cool months of the year. Gradually, the new applications of old principles have brought the possibility of year-round ideal manufacturing conditions in industrial plants.

★The success achieved in industrial air conditioning suggested the possibilities in conditioning primarily for comfort. Theatres, restaurants, and stores—which always had suffered a hot-weather decline in business—offered a fertile field. In theatres, the cooled air increased business during the summer to a point never before known. Restaurants and stores also enjoyed the new summer prosperity. Thus air conditioning for comfort was established. Public demand for greater summer comfort, and the success of air-conditioning engineers in achieving it, gave impetus to the work of residential air conditioning.

★Few industries have enjoyed as rapid a development as air conditioning, and few industries have such potentialities. Air conditioning includes the treatment of air in one or a combination of several of the following ways: heating, cooling, humidifying, dehumidifying, ventilating, and cleaning. The air-conditioning industry is demanding trained men to carry on the work of improving and installing all types of systems, from those used in factories to those used in homes. The training necessary for this work is peculiar to the industry and highly technical.

★These volumes aim to meet the needs of men who, with the demand of the industry for specialized training in mind, look forward to joining those who are building the air-conditioning industry.

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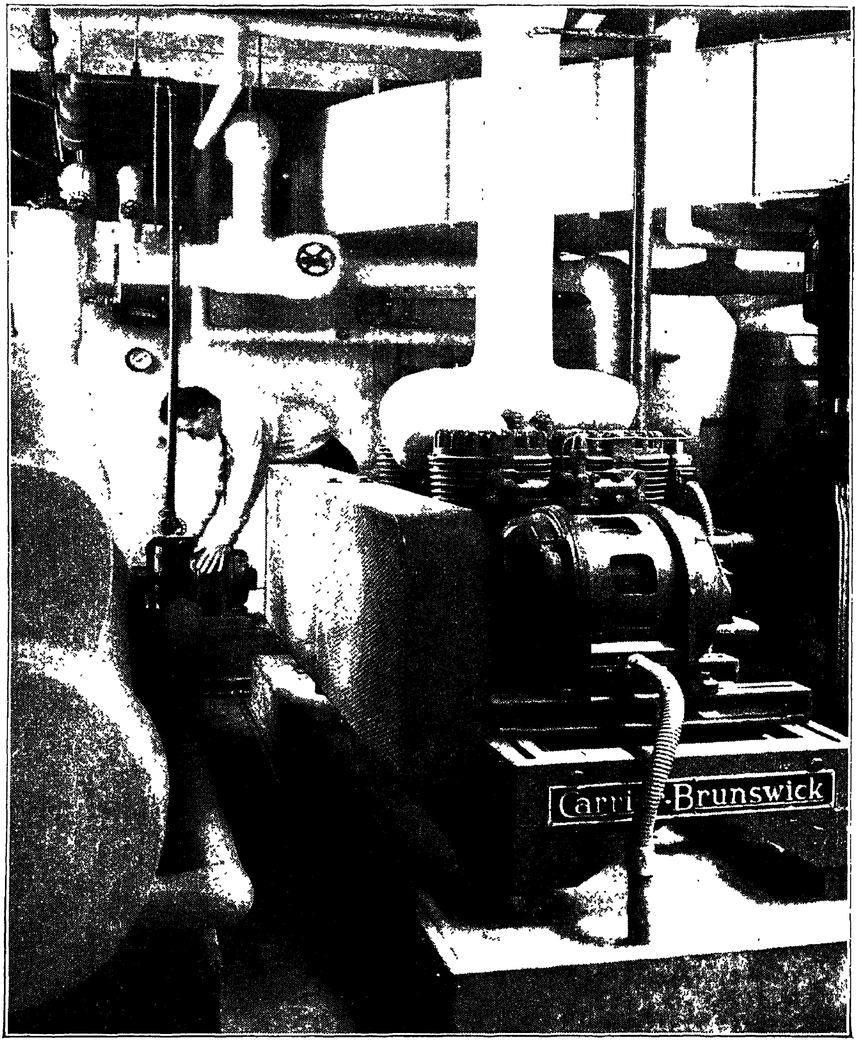
†For professional standing of authors, see list of Authors and Collaborators at front of volume.



SHOWING AIR-CONDITIONING UNITS IN THE CORNING GLASS BUILDING, NEW YORK CITY

Courtesy of Carrier Corporation, Syracuse, N. Y.

INSULATION

CHAPTER I

INTRODUCTION

The subject here discussed covers the application of Insulation to residences and other buildings and their common building accessories. Consideration is given to origin, particular uses, physical properties, design, calculation of transmission, kinds of insulation, estimating, etc. All of these aim to instruct the reader in basic principles and their application to the more common types of buildings.

What is Insulation? Most people know the function of insulation as applied to an electric wire. The layman knows that this insulation means some material on the wire to isolate the electric current or keep it within the wire, so that the current will not come in contact with any other object. He also knows that refrigerators must be insulated; otherwise the interior would not remain cold, no matter how much ice or refrigeration was used.

Insulation, then, is a *barrier*. In the case of an electric wire it is a barrier through which the current cannot pass. In the case of a refrigerator, it is a barrier against heat; the outside higher temperature is retarded from penetrating into the interior. Buildings are insulated by materials that provide a barrier against heat loss, cold gain, fire, condensation, vermin, and vibration. Boilers and pipes are protected in the same way from undue heat loss.

When insulation is used as a resistant to the passage of heat, it retards heat so that in winter the heat within a room does not easily escape through the walls and ceiling. In like manner, it makes difficult the penetration of summer heat into a house or building; thus comfortable and healthful conditions are created.

Origin. The first recorded use of insulation dates back to a period long before the Christian Era, to a time when man was still in a primitive stage. It is recorded that primitive man stripped the bark off cork oak trees to use as roofing for his crude huts. We can

surmise that probably such a use was suggested to early man by his observing that cork oak trees were perfectly protected from the tropical sun and resultant severe heat, that these trees did not attract insects, that they resisted fire, and that they possessed a rugged characteristic that defied the ravages of time and the elements.

Later, the Romans made use of cork oak bark in fabricating beehives. It has long been known that bees require an even temperature both winter and summer and that they do not produce well when their hives are too hot. There is evidence that cork was used also as a waterproofing agent due to its natural composition being largely resin which, in itself, is impervious to water. The cork oak, then, has been used for many centuries as a means of protection from heat, cold, fire and water.

The cork industry really began with the introduction of the glass bottle. Cork has served admirably as stoppers, because it is odorless and tasteless, is impervious to water, alcohol and many oils, and possesses great compressibility, elasticity and a high coefficient of friction.

The first development of cork in sheet or board form must be credited to Germany where the first slab of cork insulating material was produced. Cork cuttings which had previously been either wasted or used for loose fills between refrigerator walls, were ground to proper size, mixed with a clay binder, and molded into boards. These were very brittle and easily damaged, but their development gave impetus to the idea of board or sheet insulation.

Another method was soon developed whereby granulated cork was impregnated with asphalt or pitch and formed into sheets. This, besides serving as an excellent insulator, had qualities necessary for waterproofing, and soon was manufactured on a large scale.

This method was followed by a still further improvement. It was found that granular cork, when subjected to moderately high temperatures, would form into blocks or sheets which did not require pitch or asphalt as a binder. This resulted in a new form of cork insulation that was less of a fire hazard, and due to the lack of pitch, was much lighter in weight, easier to handle, and a much better insulating agent.

Thus improvements have followed one after the other until today cork insulation has reached its highest efficiency. The success

with cork led to a wide and tireless search for other materials, such as natural vegetable or organic matter, which could be used as well as cork, but, although many worth-while items were discovered, none had the complete efficiency of cork. The invention of artificial substances advanced rapidly until now we have a long list of them, all of which serve as well as cork.

Uses of Insulation. Perhaps the greatest use of insulation is to prevent or retard the transmission of heat and cold, and in recent years there has been a tremendous expansion of its use for this purpose. Insulation has proved to be one of the greatest boons to man insofar as comfort, economy, and safety are concerned. It has opened avenues of pleasure, industry, health, and comfort scarcely dreamed of a few decades ago. It has provided temperate living conditions in all zones, allowed advances in building utilization, and generally improved living conditions.

Fireproofing. Another wide and important use for insulation is as a fireproofing or fire-retarding agent. Not everything can be fabricated wholly fireproof, but by the use of insulation, fire can be retarded and fireproofing can be effected.

Sound Insulation. Under many conditions noise and various other sounds become intolerable. In some cases the lessening of sounds is essential. In all cases where sound control is required, insulation serves the purpose.

Condensation Insulation. This form of insulation is designed to prevent loss or discomfort due to the accumulation of moisture by condensation. An example of condensation is the droplets of moisture formed on the outside of a glass of ice water on a warm day.

Vermin Insulation. In some climates, and especially in southern portions of the United States, vermin have caused great losses. Insulation is designed to make things either unattractive to vermin or impossible of approach by them.

Vibration Insulation. Vibration can be very unpleasant and cause undesirable effects under many different circumstances. In its action it is closely related to sound. Definite insulating methods against vibration have been devised.

Prerequisites. Insulation to be used in buildings must have the following qualities:

(1) Good handling characteristics,
(2) Resistance to decay, deterioration, and odor absorption,
(3) Light weight to lower weights in construction design,
(4) Ability to retain volume dimensions,
(5) Resistance to moisture.

Good Handling Characteristics. Many good insulating materials are hard to handle efficiently with the result that the installation costs are too high. This fact should always be given very careful consideration. For example, some insulators are molded and properly shaped at the factory and can be readily applied or put in place in a building. On the other hand certain insulators are delivered in bulk; this makes necessary considerably more time and effort on the job and often results in added costs and inferior results. Also, if an insulator is of such size and shape that it requires special handling, high costs will result.

Resistance to Decay, Deterioration, and Odor Absorption. The proper installation of good insulation requires much time and ultimate cost. Considering that repair, interest, depreciation, and other expenses are considerable amounts, the insulation selected should be of a permanent nature and one that will not be readily affected by decay, odor, etc.

Light Weights. Fortunately the greatest number of good insulators are light in weight. Conduction being closely proportional to density, the characteristics of lightness and good insulating properties are very closely related. Volume dimensions, however, offer a more serious problem, because many loose insulators settle down year by year, producing areas that are eventually without insulation. Thus, it is best to use molded forms of insulation or other forms not likely to settle or change in volume.

Resistance to Moisture. Moisture greatly reduces the effectiveness of insulation. Besides, even if various forms of insulation have been made to resist moisture, they retain their efficiency only so long as the moisture-resisting element remains intact.

CHAPTER II

PHYSICS OF INSULATION *

Heat and Cold Insulation. In order to illustrate and describe the physical properties of insulation used to prevent or retard heat or cold transmission we shall first consider cork. Fig. 1 illustrates

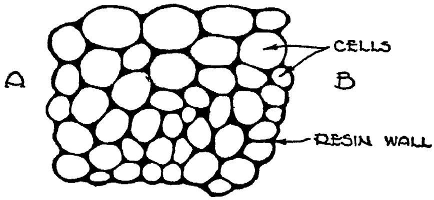


Fig. 1. Specimen of Cork under Microscope

a cross section of a piece of cork as seen under a miscroscope. It will be noted that by far the greatest part of the cork is composed of cell-like structures separated from one another by thin walls. These walls are composed of resin, which gives cork its waterproof qualities. Each cell is filled with air and tightly sealed so that the air is still or "dead."

Before continuing with our discussion of cork, it will be well to

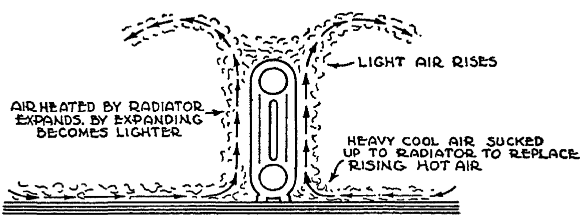


Fig. 2. Convection: Diagram of the Convection Currents Near a Steam Radiator

understand the three ways in which heat and cold are transmitted; convection, conduction, and radiation.

Convection. The common interpretation of convection is the transfer of heat by movement of air such as breezes, winds, or any movement at all, Fig. 2.

* A glossary of terms will be found on page !

Knowing these three principles of heat or cold transmission, we can again take up a study of cork (illustrative of all heat and cold insulators except a vacuum or reflection) as a means of preventing or retarding heat or cold movement. Suppose that heat is applied on the *A* side of the cork illustrated in Fig. 1. Very little heat would be conducted through the cork from *A* to *B*, because cork is 40% vegetable matter, and in vegetable matter the molecules are not very dense; thus heat transfer from molecule to molecule is not great. The cork is not transparent, so no heat would be transmitted by radiation. No appreciable amount of heat will be moved through the cork by convection because there is no movement of the dead air

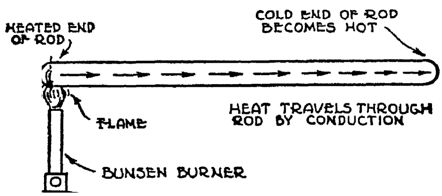


Fig. 3. Conduction: Diagram of Heat Transfer by Conduction in a Metal Rod

within the individual cells, and without air movement convection cannot take place. Cold transfer is governed exactly as is heat transfer.

Another very efficient manner of insulating against heat or cold would be by a vacuum. In fact this method would be the most efficient of all. It is not used in building work, however, because it is impractical insofar as construction is concerned.

Insulation by reflection is another method. Here some bright metal is used, the principle being that it will cause heat or cold to be reflected, thus preventing its passage.

Conduction. Heat is passed from molecule to molecule by the heat vibrations between them. Materials like metals have a very high density, resulting in rapid molecular heat transfer, but materials like cork, in which the density or molecular relation is not high, do not transfer much heat or cold, Fig. 3.

Radiation. The sun radiates heat to the earth. Heat or cold can be radiated through such materials as glass if it is in single thickness. See Fig. 4.

Fire Insulation. Many materials used in structural work are combustible; others burn slowly; still others melt and otherwise fail if not protected from heat or fire, even though they themselves will not actually ignite. Fortunately most insulating materials are either incombustible or are slow burning. The problem of insulation as a fireproofing or fire-resisting medium then becomes simply one of using as much incombustible material as practical, then insulating as a fire resistive measure, and protecting those materials that do not burn but fail if assailed by high temperatures.

Sound Insulation. Because of the complicated nature of the physics of sound, this text cannot discuss the subject in detail, but

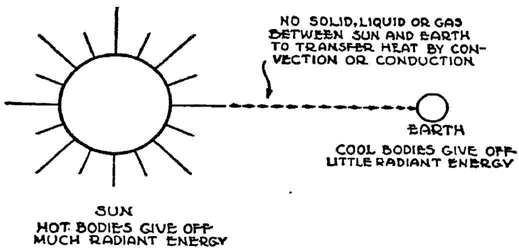


Fig. 4. Radiation: Diagram of Heat Transfer from the Sun to the Earth by Radiation

the matter can be treated sufficiently to illustrate the application of insulation.

When a firecracker or pistol explodes, the air is pushed away in all directions from the point of explosion. This causes what we know as sound. The sound travels in waves which spread from the point of origin in concentric, ever enlarging circles. This can be roughly visualized by tossing a pebble into a still pond of water and noting the circular waves or ripples that radiate from the point where the pebble struck the water. A continuous sound such as music or a whistle travels in continuous waves at regular intervals. The varying pitch of continuous sounds such as music, depends on the number of waves which we "hear" or which strike the ear per second. Other sounds which do not have regular numbers of waves per minute, nevertheless send out waves in the same manner.

When these waves strike anything quite solid they are *reflected* and continue at an angle (the degree of which can be determined by principles of Physics), and the sound, instead of gradually di-

minishing, continues until it becomes annoying or distressing to the point of being a "terrible racket." In comparatively small enclosures this reflecting actually causes a sound to be repeated in one's ear, that is, a reflected sound wave may return before the effect of the original sound on the ear has died out. Consequently the reflected sound (echo) blends with the original sound and strengthens it. The effect can readily be understood.

To retard or stop such a process we insulate against reflection, or, to be exact, we cause the sound to be absorbed and thus prevent it from blending with the original sound. The original sound and sound waves have their usual effect on one's ear, but the absorption does away with any reflection, so that no strengthening of the original sound takes place.

Absorption is accomplished by the use of soft and porous materials, such as organic felts, asbestos, hair, etc. Hard materials like metals, most woods, and glass do not absorb; therefore, they cause reflection. A manufactured material soft in nature will tend to absorb sound as a sponge takes up water; the sound gradually dies after being absorbed. A porous material, either natural or manufactured, does even better, especially if it is soft, like felt. The pores or holes in such materials are great in number, as shown in Fig. 34, Chapter III, and as the sound enters these holes friction is set up between the sound waves and the sides of the holes; this tends to further kill the sound. A great range of such materials is found in the natural state and, after adding certain material, can be molded into any form and thickness desired. Many such materials are also manufactured, vegetable matters, etc., being used in the process. For example, a fine insulating material to prevent sound reflection is made from corn stalks. Small holes are made when the molding takes place during manufacture, and add much to the efficiency of the product.

Good sound insulation, insofar as absorption is concerned, can be accomplished readily. The degree of insulation obtained is decided by economic considerations. However, such insulators as are also fire resisting should be chosen so far as possible.

Sound, like heat, travels by conduction through materials of high density. Transmission through these materials is much more rapid than through air as evidenced by the fact that by putting an

ear to a railroad rail a train can be heard long before the air-borne sound reaches us and before the train can be seen. The sound of a hammer being applied on a solid material rapidly travels along or through the material, and can be transmitted from one solid to another if the two solids touch.

Insulation requires the selection, as far as possible, of such solids as resist the passage of sound. If two solids must contact each other and cannot themselves be insulators, it is necessary to insulate the solids one from the other.

Sounds originating in open spaces are transmitted through solids which they strike. Insulation under such conditions consists of using insulating materials entirely or a percentage of such materials, in order to retard the transmission of the sound.

Open spaces cause resônance. The following experiment will illustrate this. Take a common table fork, grasp it by the handle, and strike the prongs a sharp blow. A sound is set up. Place the prongs quickly over the open end of a metal vessel of small circumference. The sound will be amplified. It is wise to avoid conditions that would cause resonance but when they are unavoidable, insulate against it.

Repeat the experiment just described but first tie the prongs of the fork together or fill the space between them with material. The sound will be greatly decreased. This indicates that insulation can be accomplished by tying or bracing parts that would otherwise be a source of continuous sound whenever a disturbance of any kind took place. Cracks and crevices will allow sound to travel from one place to another, and, therefore, should be avoided.

Vermin Insulation. Insulation against vermin, such as termites, consists of chemical treatment or protection of wood so vermin cannot reach it. There are a great many different chemicals with which wood is either soaked or painted for insulating purposes, the theory being that these chemicals render the wood unattractive to the vermin in much the same manner as moth balls make woolens unpalatable to moths. In the protection of wood from vermin by other means than chemicals, care should be taken that no wood comes within eight inches of contact with earth. Further protection is gained by the attachment of metal shields, which absolutely stop any further advance of vermin.

Vibration Insulation. When motors are running in connection with other, and especially heavy, machinery parts, fans, etc., a certain amount of vibration is created which, if not insulated against, will travel along metals and other solids, distributing the sound great distances.

It has been quite generally assumed for a great many years that if a pad of cork or of some similar material were put under machinery that was causing vibration, the transmission of the vibrations would be stopped. This is not true in all cases. If the machinery is sufficiently resilient, this method may work out, but unless the machinery is sufficiently heavy to *load* the cork so that the natural frequency of the machinery on the cork is low in comparison with the frequency of the equipment, the cork may be of little insulating value.

When air for use at a distant point is being forced through enclosures, the vibrations produced by the propelling equipment is transmitted through the air passages unless some absorption insulation is used. We have already studied those insulators which are capable of absorbing sound. These may be used in air passages so long as they do not cause too much friction. Soft insulators can be kept comparatively smooth on the surface by wire or metal nets forced down on them. If an air passage 4x6 inches in cross section is lined with an insulator having high absorptive power, the transmission of the vibrations is greatly reduced. Long and larger passages lined with a highly absorptive material are effectively insulated against vibratory noises of machinery in operation. Bends, elbows, etc., in air passages also tend materially to reduce the transmitted vibrations.

Boiler Insulation. The principle of insulation for boilers is much the same as that already explained for insulation against heat transmission. Fireproof insulating material of the kind used to prevent heat transmission is employed.

Pipe Insulation. Here the principle of heat transmission is involved and the insulator must prevent the escape of heat or cold and stand up under extremes of temperature.

Miscellaneous Insulation. The effect of humidity and temperature on sound absorption is another example of insulation, which is much different from anything so far studied. Humidity and temperature have a substantial effect on absorption of sound.

Perfectly dry air, strangely enough, is more absorptive than air containing any definite amount of moisture. Therefore, so far as noise reduction is concerned, it is best to maintain a rather dry air in order that all frequency components in sound may be absorbed.

Humidity. Humidity is the amount of water vapor present in a gas. It is also the number of pounds of liquid vapor carried by one pound of dry gas. This value is sometimes called "absolute humidity."

Relative Humidity. Relative humidity is the ratio of the weight of water actually contained in a definite volume of gas, to the weight that the same volume of gas is capable of containing when fully saturated, and at the same temperature.

The following definitions will be found of great value for all studies involving humidity, and are substantially those proposed by William Grosvenor. For general use, "air" and "water" will be considered interchangeable with "gas" and "fluids" respectively.

Percentage of Humidity is the number of pounds of liquid vapor carried by one pound of dry gas at a definite temperature, divided by the number of pounds of vapor which one pound of dry gas would carry if completely saturated at the same temperature. Percentage of humidity and per cent relative humidity are not the same, as will be shown later, and a clear understanding of their difference should be gained.

Per Cent Relative Humidity is the percentage ratio existing between the actual partial pressure of gas-liquid mixture and the total partial pressure of the saturated mixture.

Dew Point is that temperature at which a given mixture of gas and liquid is saturated with liquid vapor. It is the temperature at which the liquid vapor pressure equals the partial vapor pressure of the liquid in the gas.

Humid Heat is the quantity of heat necessary to raise the temperature of one pound of dry gas plus its contained liquid vapor, one degree Fahrenheit. Since specific heat consists of dry gas, and since liquid vapors are substantially constant for the temperature range under consideration, the humid heat is calculated from the formula:

$$S = .238 + .48$$

where S is the humid heat and .238 and .48 are the specific heats of air and water vapor respectively.

Humid Volume is the volume of one pound of dry gas together with the liquid vapor it contains. In English units this volume is expressed in cubic feet and is dependent upon the pressure, temperature, and humidity of the mixture.

Saturated Volume is the volume of one pound of dry air together with the amount of liquid vapor it contains when saturated.

Specific Volume is the number of cubic feet occupied by one pound of gas under standard conditions; it increases by its linear dimension with temperature.

There are several methods by which the water content of a gas may be determined, but the simplest and most generally used is by wet and dry bulb thermometers. The mechanism of vaporization is of great importance in the engineering field.

If a liquid be placed in a gas having a humidity less than saturation, the liquid will evaporate and diffuse into the gas medium. The rate at which evaporation takes place will be proportional to the total area of the liquid and to the difference in the partial pressure of the vapor in the air and the partial pressure of the liquid. If the liquid area is A; its temperature and pressure values t_1 and p_1 respectively; its weight w; if the partial pressure of its vapor is p_2 at a temperature of t_2 and k is the diffusion coefficient through the gas film, the amount of evaporation for differential time will be

$$\frac{dW}{d\theta} = kA\ (P_1 - P_2)$$

If t_2 is higher than t_1, which is to say that the temperature of the gas medium surrounding the liquid is higher than the temperature of the liquid, heat will flow from the gas to the liquid at a rate,

$$\frac{dQ}{d\theta} = hA\ (t_2 - t_1)$$

where h is the coefficient of heat transmission through the gas film in the liquid. The heat flow from the gas to liquid medium, raises the temperature of the liquid and increases its rate of evaporation, but decreases the over-all temperature difference until a dynamic condition is established between the two mediums. When equilibrium is established, the rate of heat flow from gas to liquid will be equal to the heat vaporization per unit of liquid:

$$\frac{dQ}{d\theta} - \frac{RdW}{d\theta} = KAR\ (P_1 - P_2) = bA\ (t_2 - t_1)$$

Combining and simplifying the above,

$$(P_1 - P_2) = \frac{h}{kr}\ (t_2 - t_1)$$

or, since the value of change is small over the usable temperature range,

$$(P_1 - P_2) = k_o\ (t_2 - t_1);\ \text{where } k_o = \frac{h}{kr}$$

Fig. 5.

Taylor Sling Psychrometer. The advantage of this form of Wet-and-dry-bulb Hygrometer over the stationary form is the facility with which tests can be made and the accuracy of the readings obtainable, as in whirling the bulbs they are subjected to perfect circulation. Consists of two accurately etched stem thermometers mounted on a die-cast frame, with the bulb of one covered with a wick to be moistened.

These thermometers have scales of 0° to 100° F., graduated in ½-degree divisions. A copper case protects the tubes when not in use.

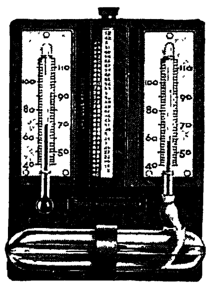


Fig. 6.

Taylor Humidiguide. A handsome small hygrometer for the wall of the home, office, school or other buildings where a neat, easily read and inexpensive instrument is desired. It is self-contained, requiring no charts or separate tables. Frame is Mahogany Bakelite.

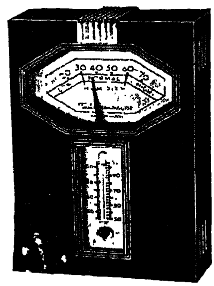


Fig. 7.

Taylor Hampton-Model Humidiguide. (Direct Reading)—A hygrometer giving direct humidity percentages, in a smart, modern case suitable for home, office or public buildings. Finish is satin black with chrome trim.

The Permacolor Thermometer is filled with non-fading red liquid, easily read.

Courtesy of Taylor Instrument Company, Rochester, New York

How to Find Relative Humidity. This can be done readily by using a sling psychrometer (see Fig. 5) or, the Psychrometric Chart

in the back of the book. If a sling psychrometer is not available, however, an ordinary dry bulb thermometer (such as is used ordinarily for temperature readings) will serve the purpose though a little additional work is involved.

To find relative humidity, the dry bulb temperature of a room, or any other space, is obtained by leaving the dry bulb thermometer (for a few minutes) in the area to be tested. For the wet bulb test it is advisable to place a cup of water in the room one day previous to making the test so that the temperature of the water will be the same as that of the area being tested.

After the dry bulb reading has been taken, tie a small piece of muslin or some similar material around the mercury-well end of the thermometer. Dip this in the cup of water and, taking hold of a string tied to the upper end, swing the thermometer around in the air for about half a minute.

Note the drop in temperature from the original dry bulb reading. Re-wet the muslin wick and swing the thermometer again for a like period of time to make sure the maximum drop in temperature has taken place. The temperature difference should then be noted. Then, both wet and dry bulb temperatures being known, the psychrometric chart in the back of the book can be used to determine the relative humidity. The point of intersection of the vertical line from the dry bulb temperature on the chart, and the diagonal line from the wet bulb temperature, gives the relative humidity. For example, turn to the psychrometric chart in the back of the book. Assume a dry bulb temperature of 70° F. and a wet bulb temperature of 61° F. From the 70 on the bottom of the chart follow the vertical line upward until it intersects the slanting line from 61° on the curved wet bulb temperature line. They meet at the percentage of humidity line marked 60%. Therefore the relative humidity is 60%. The above method is probably one of the simplest used for this purpose and if carried on carefully, accurate results can be obtained.

There are instruments that give the relative humidity at a single reading such as those illustrated in Figs. 6 and 7. Such instruments can also be depended on for accurate figures.

Condensation. Condensation of the vapor content of air is a common phenomenon that frequently assumes serious importance

in domestic and industrial buildings. Since there is such a general misconception concerning the mechanism of condensation, an analysis of its causes, remedies, and relation to humidity will be taken up.

Relation to Humidity. It was pointed out in the section on humidity that the wet and dry bulb temperature relationship is the basis for calculating the relative humidity. When the two readings are widely separated, the humidity will be low; and when they are near together the humidity will be high. In other words, the nearer the two temperatures become, the higher will be the humidity. The limits of per cent relative humidity are obviously zero and 100%; and it is readily seen that if the wet and dry bulb temperatures reach the same value, the humidity will be maximum, or 100%. When the humidity of any system reaches a maximum value, the system is said to be saturated. This point of saturation is also referred to as the "dew point."

Theoretical Concept. Let us assume that we have a definite amount of air saturated with water vapor at any temperature. If this air-vapor mixture is cooled one degree Fahrenheit, the air will contract a definite proportion of its volume and will release a definite amount of its water content, the amount of water released being just sufficient to re-establish saturation equilibrium at the new temperature. The definite amount of water expelled when the gas was cooled the one degree Fahrenheit represents the difference between the total water carrying capacities of the gas at the two temperatures. If the gas is further cooled, it will continue to throw off its water content, the amount of water thrown off always representing the excess over saturation. Conversely, if the saturated gas is heated, it will expand in volume and its total water carrying capacity will be increased.

Mechanical Concept. The mechanism of air-water vapor mixtures under temperature variations is exactly like the behavior of a sponge under varying pressure conditions. If a sponge, saturated with water is gradually compressed, that is, has its volume decreased, the sponge will lose water, the amount of water released depending upon the degree of compression. If the sponge is kept in contact with the water released during the first stages of compression and the pressure then is released, the water will be reabsorbed. In other words, the sponge will always be saturated and will always carry the maximum amount of water possible for any given imposed pres-

sure. From a mechanical standpoint, the amount of water a sponge is capable of holding is dependent on the total free space volume of the capillaries within the sponge; in like manner, the total vapor carrying capacity of a gas is dependent on the free space volume existing between the gas molecules. Decreasing the free space ratio decreases the carrying capacity of any medium, while increasing the free space ratio increases the carrying capacity. With this conception of the behavior of gases and their vapor content in mind, consider the causes and remedies of condensation.

Causes of Condensation. It has been shown that when saturated gaseous-vapor systems are cooled, water will be thrown out, the water removed being termed "water of condensation." Condensation can never take place through temperature changes alone, above the dew point, or vapor saturation temperature.

Let us see what occurs in a room having an uninsulated roof. The air within the room is assumed to have a high per cent relative humidity. As the walls and roof lose heat and cool, heat will flow from the warmer sections of walls and roof to the exposed surfaces, thus removing heat from the air in direct contact with the wall and roof areas. When heat is removed from the air in contact with the walls and roof, it will contract in volume and will give up a certain amount of its water content as water of condensation, providing the total temperature drop, due to loss of heat, is sufficient to reach or exceed the dew point temperature. This water of condensation will be thrown out from the cooling air onto the cool wall and roof surfaces. Besides, cooler air will descend and will be replaced by an inflow of warmer air which, in turn, will be cooled, give up excess of water as water of condensation to the walls of the building, and then sink. The resultant condensation caused by the cooling vapor-carrying air to a temperature below its dew point will eventually reach a quantity sufficient to cause the water to run down the walls or to drip from the ceiling. It is thus seen that condensation is brought about by cooling air which contains a large percentage of water, to or below its dew point. Remedying such a condition is. therefore, merely a matter of preventing heat losses through the wall and roof materials.

Remedies for Condensation. Insulation of roof sections is always desirable from a heat saving standpoint alone, and is of es-

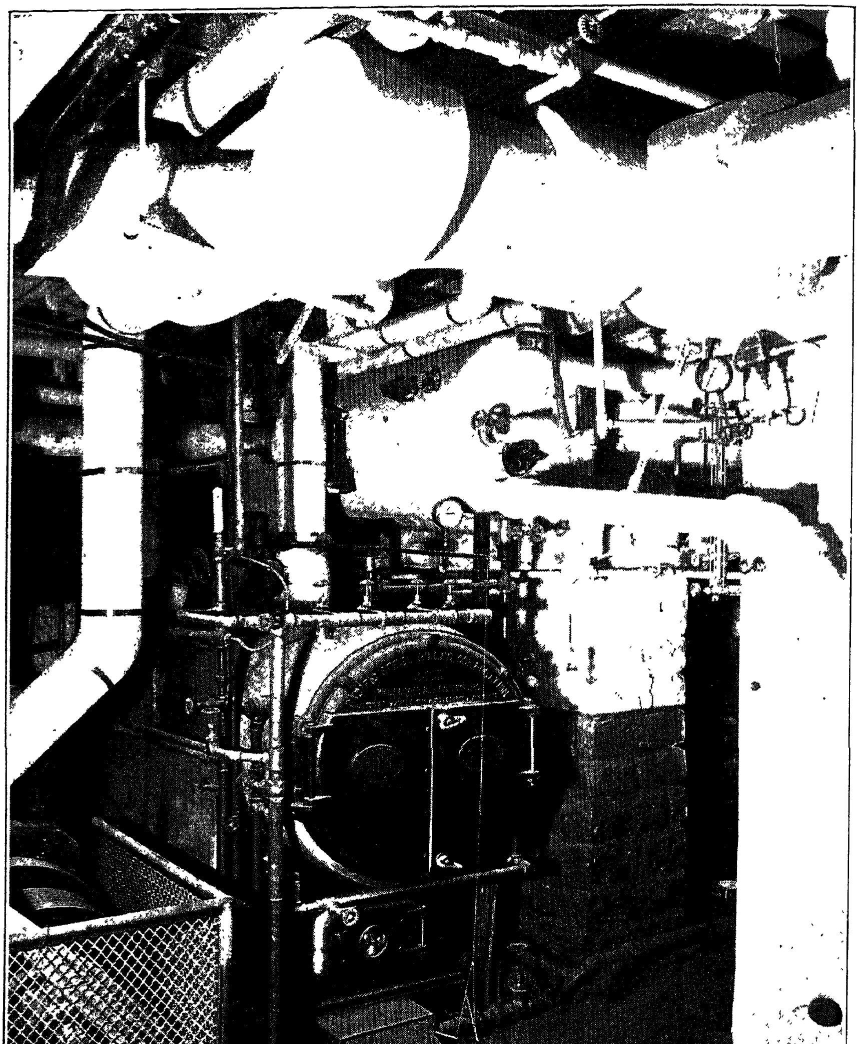
sential importance in many industrial establishments such as paper mills, laundries, dye works, tanneries, textile mills, etc., in which high humidity occurs.

The fundamental things that must be kept in mind in all condensation problems are: that condensation is the primary result of heat losses through the wall and roof sections; that it is the secondary result of lowering the temperature of the humid air to or below its saturation, or dew point, temperature; and that condensation correction is always the stoppage of heat losses, through the proper use of efficient insulation.

The stoppage of heat losses through wall and roof constructions depends solely upon raising the overall thermal resistance of the sections. In other words, increasing the thermal resistance of a section decreases the rate of heat energy flow and produces a higher constant temperature at the gas-solid junction. Adequately increasing the constant temperature of the gas-solid junction produces a condition in which the humid air is always maintained at a temperature above its dew point. Humid systems having minimum temperatures above their dew points have been shown incapable of condensing their vapor content; and it is, therefore, possible to select conditions that will make condensation impossible.

It is felt that the above points offer the basis for intelligent treatment of condensation effects, but if more detailed information is desired concerning the calculation of roof losses, the reader is referred to the section on roof insulation.

In Chapter VII will be found a detailed explanation of the application of the condensation theory. The foregoing information is of a general nature while the material in Chapter VII gives specific data and tables for use in actual design work. Chapters V and VII give more detailed information on all other topics mentioned in Chapter II.



APPLICATION OF RUBEROID INSULATION IN A TYPICAL BOILER ROOM

Courtesy of The Ruberoid Company, New York

CHAPTER III

KINDS OF INSULATION

This chapter aims to acquaint the reader with insulation as to form, type manufacture, dimensions, etc. Not all kinds or types can be explained here, but a sufficient number will be discussed to insure the reader a perfect understanding of types and what each type accomplishes. The types or kinds chosen were selected only

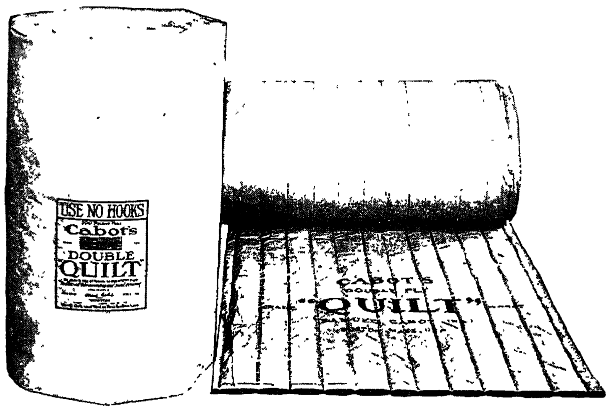


Fig. 8. Cabot's Quilt
Courtesy of Samuel Cabot Incorporated, Boston, Massachusetts

as examples and the choice does not imply that any one is better than another.

Quilt Type. To illustrate this type, Cabot's Quilt, Fig. 8, will be used. This particular brand is typical of quilt insulation.

Cabot's Quilt is a thick, springy matting of cured Zostera Marina stitched between sheets of the toughest kraft paper (standard quilt), or other cover materials (special types of quilt). Zostera Marina is a marine plant, gathered on the Bay of Fundy, and is largely composed of silica (instead of carbon, which makes up vegetable growths in the air). Consequently Zostera Marina is non-inflammable. The natural iodine content keeps it free from vermin and rot. It has a long, crinkly fibre, and when matted into the quilt forms

thousands of tiny air cells in every layer. Dead air in cells is one of the most perfect insulators known.

Cabot's Quilt combines high insulating power, low cost, ease of installation, resistance to spread of fire, sanitary nature, and permanence. Thus the most inexpensive building, through its use, can have as perfect insulation as the most costly.

Standard Quilt. Standard quilt is made with envelope of tough, heavy kraft paper.

Special Types of Quilt. In addition to the standard quilt, there are a number of special types, using other envelope materials than the standard kraft paper. These include the following:

(1) Waterproof quilt, with envelope of different weights and types of waterproof paper, for insulation in roofs, walls, and other places where dampness or moisture must be dealt with.

(2) Asbestos quilt.

(3) The new Anti-Pyre quilt constructed with chemically treated non-inflammable paper envelope; this, together with the acknowledged non-inflammability of Zostera Marina, enables this quilt to meet the most rigid requirements of fireproof construction; it will not support combustion.

Weights or Thicknesses of Quilt include the following:

(1) Single-Ply (X); commonly used for lining houses in place of the building paper ordinarily employed between the inner and outer sheathing. It is about ⅛ inch thick, and one layer is equal in insulating value to 28 layers of common paper.

(2) Double-Ply (XX); used for sound-deadening in all houses and similar structures where a thorough job of insulation is required. One layer of double-ply quilt is equal to more than forty layers of common paper. By scientific tests it has also been shown that one layer of double-ply quilt is a somewhat better insulator than a 12-inch brick wall.

(3) Triple-Ply (XXX); for cold storage or for use under conditions where more effective results are desired than can be obtained with double-ply. It is about ⅜ inch thick.

(4) Inch Quilt; for special service and maximum sound and heat insulation.

Widths of Quilt. Quilt is made in two widths, 36 and 18 inches. The 18-inch is made for easy installation between studs and rafters.

The coefficient for Cabot's Quilt will be found in Tables 2 and 14. In Table 2 it is called Eel Grass, which is another name for the marine plant called Zostera Marina. The coefficients are used in such formulas as (2) to (7) in Chapter V.

Wool Type. There are many kinds of rock and mineral wool on the market, and indications are that the number will continue to grow. In general, these are designed for one common purpose—insulation. The service they give in actual usage is contingent upon the type and quality of the raw materials used in manufacture, and

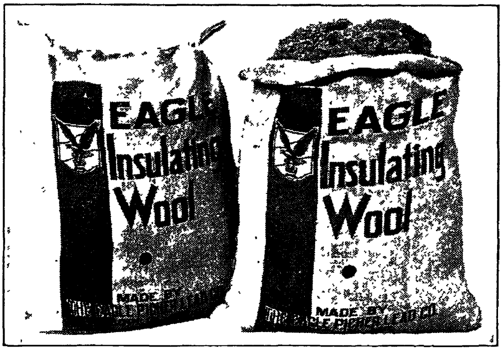


Fig. 9. Eagle Insulating Wool
Courtesy of Eagle-Picher Company, Cincinnati, Ohio

the supervision and scientific control exercised over the manufacturing process. This is an important point, because while it is simple to produce a rock or mineral wool, it is by no means simple to produce effective insulation. On the contrary, the process is most exacting, and necessitates the most rigid supervision and the background of exhaustive research.

Eagle Home Insulation is composed largely of flint-rock, with portions of limestone, and other siliceous minerals carefully selected after exhaustive experimentation with a wide variety of raw materials. These are compounded in such proportions as to produce a material of outstanding insulating efficiency, and one which is readily adaptable for use in all types of building construction—a flexible product that may be installed speedily and with minimum effort. The outstanding flexibility makes it uniquely suited for application in homes by the pneumatic process, Fig. 9.

In the manufacturing operation, the ingredients are melted in especially designed furnaces at a temperature of about 3000° F. They become thoroughly blended into a molten mixture which flows in an even stream through a spout at the bottom. As this stream leaves the spout, it is blown by a jet of live steam. The steam transforms the molten mixture into a mass of small pellets or globules, which are hurled by its force into a larger chamber, known as the "blow room." As the globules rush through space at high speed, a soft, flexible fibre is formed and upon falling to the floor, the fibres assume a resilient, "wooly" consistency containing millions of minute, fully enclosed, dead air cells. These tiny air-pockets give insulation its insulating efficiency.

The product is then passed through a highly mechanized process which eliminates any particles not thoroughly fiberized. Insulation emerges a fluffy, light, hair-like material composed of tough, yet soft and pliant fibres.

The entire process is carried on under constant laboratory supervision supported by the thorough knowledge and experience of research engineers. Every phase of the operation contributes toward producing efficient insulation, and not toward producing merely another rock or mineral wool. For example, the temperature of 3000° F. is much higher than necessary to bring the mass to a molten state. But laboratories have found that this temperature plays an important rôle in properly fusing the ingredients so as to bring out their maximum efficiency. Similarly, the specific grade of coke used is higher priced and more difficult to secure than many grades which could be employed. But engineers have discovered, through exhaustive tests, that the chemical properties of this particular coke have direct bearing on the excellent quality of the insulation.

Red Top wool is another typical brand and is made from silica sand, soda ash, and limestone by a process similar to that explained for the above named wool. Fig. 10 shows Red Top wool. It is a fluffy, light, white material, as further illustrated in Fig. 11.

There are other makes of wool insulating materials, but all of them are quite similar to the two makes mentioned. Generally the wool is purchased in bags and is delivered to the job in this manner.

The coefficients are shown in Tables 2 and 14. More about the uses of wool will be found in Chapter IV.

Bat Type. This type of insulation comes in "pads," usually called "bats." These bats are madė of wool insulation.

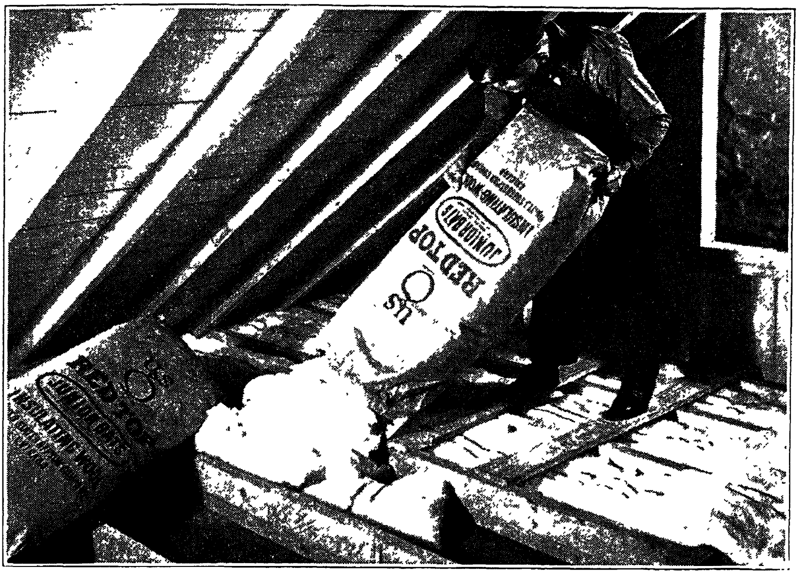


Fig. 10. Applying Red Top Wool
Courtesy of U. S. Gypsum Company, Chicago, Illinois

Fig. 11. The Long, Silklike Fibers of Red Top Wool
Courtesy of U. S. Gypsum Company, Chicago, Illinois

They are rectangular in shape and will fit their places of application snugly because they can easily be cut to any shape, as illustrated

in Figs. 12 and 13. They retain their shape because of a heavy paper covering, and are therefore easy to apply. They come in sizes of approximately 15 by 18 inches. Being wool they are very slow

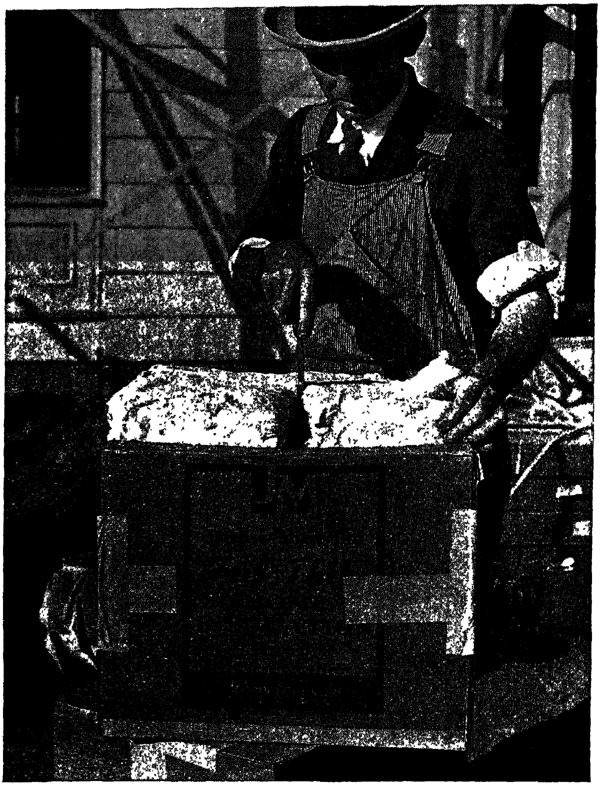


Fig. 12. Cutting Bat Insulation
Courtesy of Johns-Manville Company. New York

burning and make an excellent fire stop They are delivered in large packages or cartons.

Coefficients will be found in Tables 2 and 14. Use and design of bat type insulation is explained in Chapter IV.

Blanket Type. Eagle type blankets, Fig. 14, are made of insulating wool as previously explained. The wool is carefully felted and secured between metal fabric of various types. No binding agent or other material is introduced in their manufacture. They

contain the maximum amount of wool uniformly packed to correct density, thus providing high insulating efficiency. The blankets are strong and resist shipping easily. They contain tough, flexible fibres

Fig. 13. Showing How Irregular Spaces around Doors or Windows Are Easily Filled by Cutting Bats to Exact Size

which prevent breakdown or settling and thus assure proper resistance. Strong metal fabrics are used in their manufacture. Copper bearing lath and tie wires are used to provide great strength and to

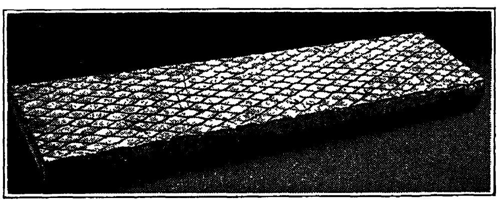


Fig. 14. Blanket Insulation for Large Surfaces
Courtesy of Eagle-Picher Company, Cincinnati, Ohio

insure long service. These blankets can be secured in pieces 2 by 4 feet and 2 by 8 feet. They can be secured also in either flexible or rigid form. The following shows the standard styles of Eagle Blanket Insulation:

200 1-inch wire mesh on both sides
200-A Stucco lath on both sides
200-B 1-inch wire mesh and stucco lath
201 Stucco lath and expanded lath
201-A 1-inch wire mesh and expanded lath
202 Expanded lath on both sides
203 Stucco lath and ⅜-inch rib lath
203-A Same as 203, except rib turned out*
203-B 1-inch wire mesh and ⅜-inch rib lath
203-C Same as 203-B, except rib turned out*
204 Expanded lath and ⅜-inch rib lath
204-A Same as 204, except rib turned out*
205 Stucco lath and ¾-inch rib lath
205-A Same as 205, except rib turned out*
206 Expanded lath and ¾-inch rib lath
206-A Same as 206, except rib turned out*
207 ⅜-inch rib lath on both sides
207-A Same as 207, except rib turned out on one side*
208 No. 12 mesh fly screen on both sides

Standard Sizes, 2x4 feet and 2x8 feet, in thicknesses of 1 inch, 1¼, 1½, 1¾, 2, 2½, 3, 3½, 4, 4½, 5, 5½, 6, 6½, 7, 7½, and 8 inches.

Fig. 15. Section of Balsam Wool Blanket
Courtesy of Wood Conversion Company, St. Paul, Minnesota

Special Sizes: all dimensions other than those listed as standard are considered special sizes. Special thicknesses are available.

Recommended Blanket Thickness

Operating Temperature Degrees F.	Recommended Thickness of Eagle Blankets, Inches	Operating Temperature Degrees F.	Recommended Thickness of Eagle Blankets, Inches
100 to 200	1	701 to 900	3
201 to 300	1½	901 to 1100	3½
301 to 500	2	1101 to 1200	4
501 to 700	2½	....	....

Note. Table does not include the ½-inch coat of Eagle "66" Plastic Insulation with which blankets are finished.

Fig. 15 shows a Balsam Wool blanket. Balsam Wool is made from wood fibres in fleecy wool form, permanently matted together and treated chemically to resist fire. This wool is put between two sheets of asphalt-coated, tough, creped kraft paper. In Balsam Wool the natural heat resistance of the wood is multiplied many times by a rearrangement of the cellular wood fibers into a "wool" form which retards the circulation of air. The still air space in Balsam Wool is approximately 92 per cent, while its density in pounds

* In many industries, there is a demand for an air space between the insulation and the hot surface. These blankets are especially designed to meet that need. The turned out rib provides the required air space.

per cubic foot is only 3.62. The fact that the paper liners of Balsam Wool are not stitched or punctured in any way adds further to its heat, moisture, and wind resisting qualities.

The standard widths are 17, 25, and 33 inches. The standard thicknesses are ½ and 1 inch. The ½-inch thickness weighs 240 pounds per 1000 square feet, and the 1-inch thickness 370 pounds per 1000 square feet.

Fig. 16 shows Red Top Strip or Blanket Wool. This type is

Fig. 16. Applying Strips or Blankets
Courtesy of U. S. Gypsum Company, Chicago, Illinois

made in a continuous 9-foot strip, 4-inches thick, and from 15 to 23 inches wide. It is shipped in cartons containing 33¾ square feet consisting of three strips, each folded into thirds for easy removal and application. A heavy paper is cemented to the back of each strip. This type is also made in 2-inch paper-backed thickness. The wool is the same as shown in Fig. 11. Coefficients will be found in Tables 2 and 14. Use and design are explained in Chapter IV.

Alfol Type. Alfol is a pure aluminum foil. As insulation it consists of single or multiple sheets of the foil installed in places where insulation is needed. The reflection of heat is the principle upon which Alfol is based, in conjunction with the dead air space provided by crumpling the foil, or by using it in panels or frames. The

theory is that when heat, for example, strikes Alfol it is reflected to a large extent and is thus prevented from a free passage through walls or members and parts. The dead air space theory is the same as explained in Chapter II.

In order to make Alfol insulation efficient, fill up the insulating space, and have dead air space between the sheets, the foil is crumpled so that its surface will be in ridges and valleys. The foil is embossed

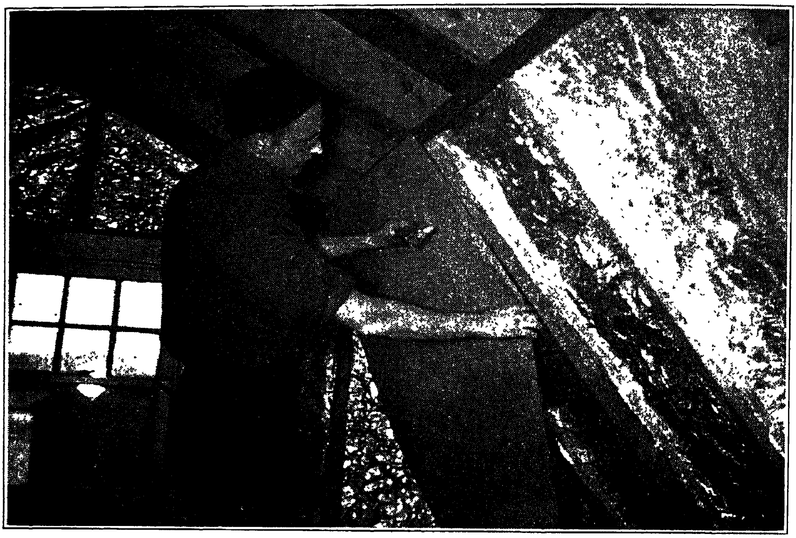


Fig. 17. Aluminum Foil Insulation
Courtesy of Alfol Insulation Company, New York

to make these bends angular and thus give minimum points of contact. Fig. 17 shows surface of crumpled Alfol.

There are two general methods of using aluminum foil for insulation. In one a framework is provided which supports the foil and forms a series of air cells between the bright foil surfaces; in the other the foil is first crumpled, as explained, and partially stretched so that the resulting wrinkles in the foil support the separate sheets when they are laid against each other and provide the necessary separation and air cells.

Alfol reflects heat as a mirror reflects light. Ninety-five per cent of the radiated heat which tends to flow through Alfol insulated

walls, ceilings, and roofs, is reflected back into the house, where it is needed. Practically none of the heat is stored up in Alfol. Alfol reflects it immediately. Therefore the supplied heat immediately heats the air in the house, instead of heating up the structure itself. This naturally results in warming the house more quickly on cold winter mornings, and at a low fuel cost.

Conversely, in hot summer weather Alfol reflects the sun's heat from the house and keeps it comfortable. It does not retain stifling daytime heat all during the night. When nighttime coolness arrives, the insulation temperature immediately drops and the house becomes cool at once. This is because Alfol has no heat storage capacity.

Alfol does not store heat, is not harmed by wetting, is fireproof, does not swell or warp, and can be used where temperatures rise as high as 1250° F. Thermal insulation with a metal is made possible by taking advantage of the low thermal emissivity of aluminum foil and the low thermal conductivity of air. It is possible with this type of insulation practically to eliminate heat transfer by radiation and convection, and to approach the insulating value of still air. The aluminum foil and air-cell insulations of the plain air-cell type are found to be better than structures with corrugated separators or crumpled foil. The best results are obtained when the distance between foils is from 0.25 to 0.33 inch (0.64 to 0.84cm.). The light weight of aluminum foil and air-cell insulation, and its excellent insulation properties, make it especially suitable for use in the transportation industry.

Alfol is supplied in widths of 16, 18, 20, 22, 24 and 26 inches; in rolls containing either 2,000 or 3,000 square feet, weighing from 10 to 20 pounds.

To crumple Alfol easily and quickly, place the roll on a reel. While one man turns the reel, the second man unrolls about ten feet of foil and places several feet over his left forearm. Then, while the man at the reel unwinds the foil, he flips his left wrist, throwing the foil up with his left hand, and with his right hand lightly beats the foil down. He then flips up his left hand and beats down with his right hand alternately. The movement of the left and right hands must be timed so they alternate smoothly. The foil should not be struck with much strength, and not grabbed and pulled. The proper

movement of the hands will make the foil pass between the hands without actually pulling it. It then passes lightly by the body and

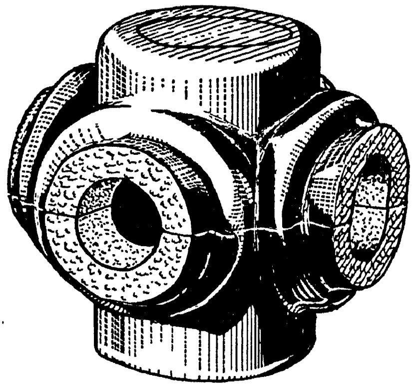


Fig. 18A. Special Cover for Screwed Four-way Valve

falls to the floor. Two experienced men can crumple two thousand square feet of Alfol in ten minutes.

For convenience, only two or three hundred linear feet of foil

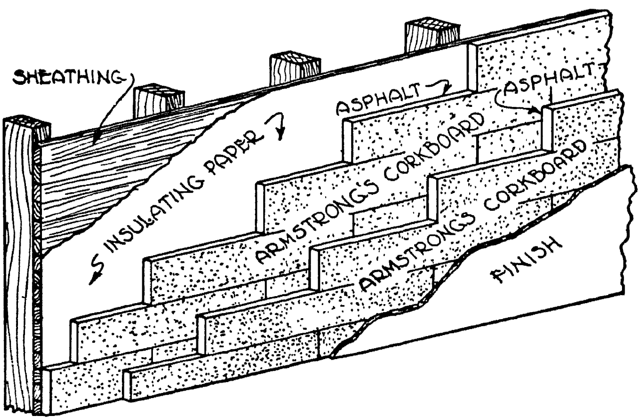


Fig. 18B. Wood Wall with Two Layers of Corkboard Applied in Asphalt

are crumpled at a time. Then the sheet is torn from the roll on the reel. The free end of the foil is pulled from the pile of crumpled foil on the floor and at the same time slightly stretched, so that the surface resembles the photographic view, Fig. 17. It can then be cut

to the right length, preparatory to being hung in place, Fig. 17.

Coefficients will be found in Table 2; applications and design in Chapters IV and VIII.

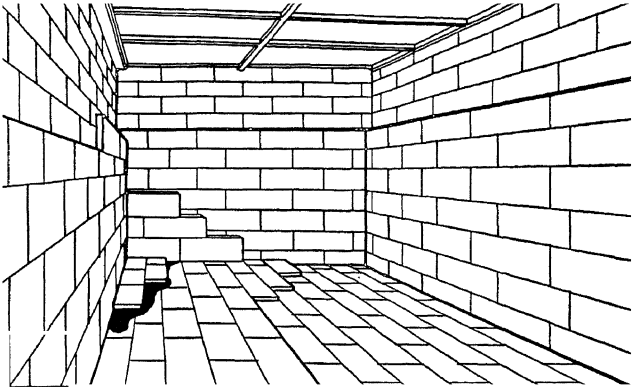


Fig. 18C. An Installation of Corkboard Insulation

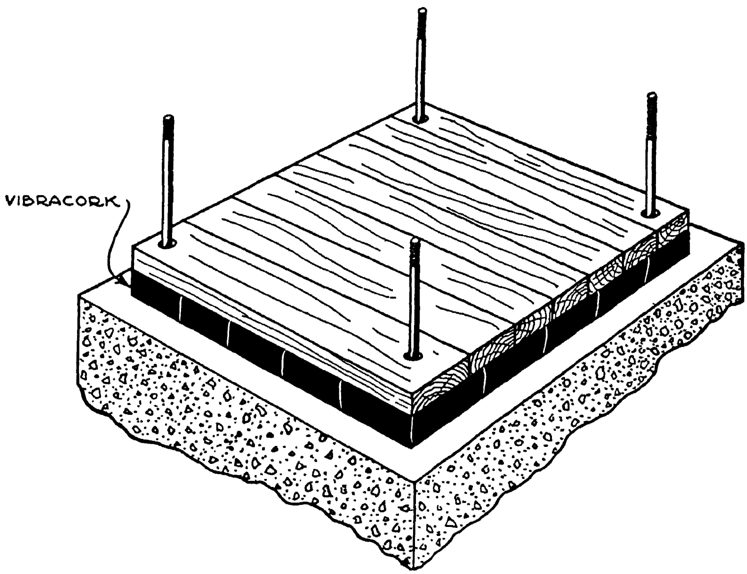


Fig. 18D. Foundation for a Machine Insulated with Vibracork

Cork Type. Figs. 18A, 18B, 18C, and 18D illustrate typical cork types of insulation and various applications of Armstrong cork insulation.

Cork covering, corkboard, and vibracork are all made by essentially the same process. They consist of cork particles carefully ground, sized, cleaned, and baked in molds under pressure. The baking process brings out certain of the gums and resins in the cork and binds the material into a homogenous mass.

Cork covering is corkboard material made in pipe covering form, Fig. 18A, to fit standard pipe and pipe fittings. Covering for straight pipe is in molded half-sectional form; coverings for fittings are molded in half sections to fit the necessary fittings; and large-sized pipe and fitting covers are furnished in logging form which may be assembled in sectional form at the factory.

Corkboard, Figs. 18B and 18C, is made in standard sizes 12x36, 18x36 and 36x36 inches and in thicknesses of 1, 1½, 2, 2½, 3, 4, and 6 inches.

Vibracork, Fig. 18D, can be obtained in standard sizes 12x36 inches and in thicknesses of 1, 1½, 2, 3, 4, and 6 inches.

Pipe Covering Types. *Ruberoid Sponge Felt Pipe Covering* is composed of asbestos paper with a maximum amount of sponge evenly distributed. It has 37 to 42 laminations to the inch, and is uniformly round, rigid, and of extreme density. Sections are made to fit all pipe sizes, 3 feet long, in thicknesses from 1 inch to 3 inches. When a 3-inch thickness is furnished, it is in two-layer broken joint construction, unless the solid single layer construction is specified. Thicknesses less than 3 inches are furnished in the solid single layer construction unless otherwise specified. A canvas jacket, 3½ ounces per square yard, is attached to each section and lacquered bands are furnished, Fig. 19.

Ruberoid Anti-Sweat Insulation has been developed for use on cold water pipes. It efficiently keeps the water in the pipe colder than the average type of insulation and if properly applied completely prevents condensation or sweating of pipes.

Outstanding among all the features of Anti-Sweat is its construction. Carefully made and tightly wound, it is composed of an inner layer of asphalt-saturated asbestos paper, a half-inch of pure wool felt, 2 layers of asphalt-saturated asbestos felt, another half-inch of pure wool felt, with outer layers of deadening felts, combined with asphalt-saturated felts. The outer layer has a flap extending at least 3 inches beyond the joint. Over all is a good quality, white

canvas jacket. Brass lacquered bands for fastening to pipes are furnished.

Anti-Sweat is made in solid layer construction, in ½-inch and

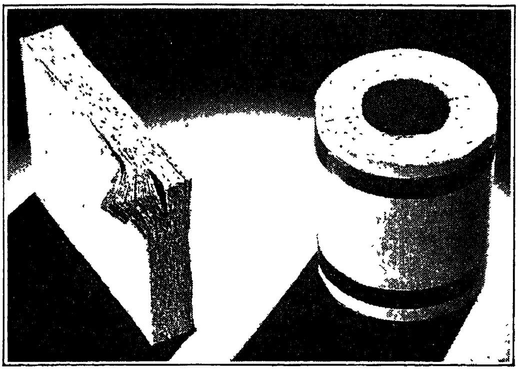


Fig. 19. Sponge Felt Pipe Insulation
Courtesy of The Ruberoid Company, New York

¾-inch thickness; 1-inch thickness and greater thicknesses are made in telescopic or broken joint construction.

If Anti-Sweat Pipe Covering is to be applied on pipe lines ex-

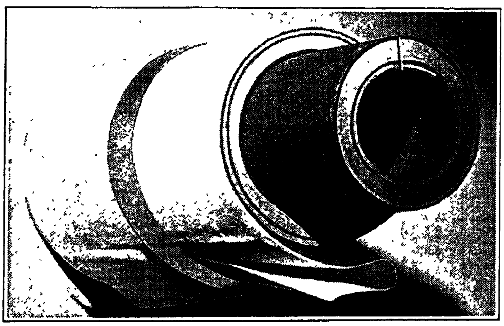


Fig. 20. Anti-Sweat Pipe Insulation
Courtesy of The Ruberoid Company, New York

posed to weather, it can be supplied with a weatherproof jacket at the factory, Fig. 20.

Ruberoid Air Cell Pipe Covering is made of fine quality asbestos paper. It is formed by layers of plain asbestos felt, alternating with

corrugated asbestos felt, each lamination or ply ¼ inch thick. Air Cell can be furnished with the regulation canvas jacket as well as the new Pyroxylin finish. The Pyroxylin finish is applied over the entire outside wrapper or casing of asbestos paper, making a glossy, pure white surface that is dust, water, oil, and grease-proof, and can be cleaned easily.

Not only is the appearance of the finished pipe covering job

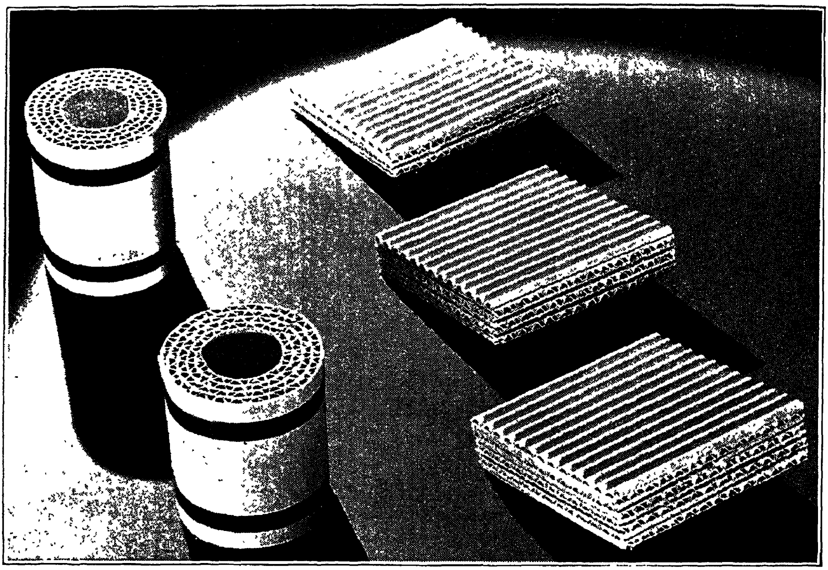


Fig. 21. Air Cell Pipe Insulation
Courtesy of The Ruberoid Company, New York

greatly enhanced with the Pyroxylin finish (no longitudinal seams are visible with this type of hinged joint construction) but the time application of the insulation to the pipe is lessened, permitting as many as three sections of Pyroxylin-finished pipe covering to be applied in the length of time it would take to apply a single section of canvas covered material.

Note. See specifications page 218.

Ruberoid Air Cell Covering, Fig. 21, is light in weight, yet possesses considerable rigidity and strength. It cuts cleanly and easily with knife or saw, and can be removed and re-applied without

injury. It is most effective for temperatures not in excess of 300° F.

When furnished with the standard canvas jacket, brass lacquered bands, ¾ inch wide, are supplied for application. With Pyroxylin Finish 1 inch wide, black japanned bands are supplied, 3 per section.

Sections are 3 feet long; thicknesses of ½ inch (2 ply) ¾ inch (3 ply) and 1 inch (4 ply). Made to fit all standard pipe sizes. Packed in dust-proof cartons.

Ruberoid 85 per cent Magnesia Sectional Insulation, Fig. 22, is composed of approximately 85 per cent pure carbonate of magnesia

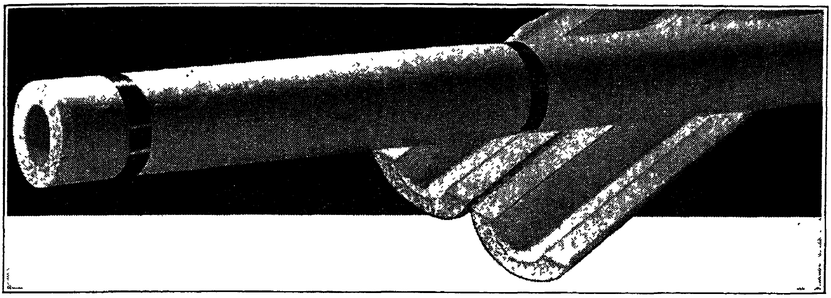


Fig. 22. 85 Per Cent Magnesia Pipe Insulation
Courtesy of The Ruberoid Company, New York

and carded long asbestos fibre. This product is manufactured by a process under which bittern and a solution of *Trona* are scientifically mixed, with a resultant precipitation forming the basic magnesium carbonate. Under the influence of heat and other factors, this precipitate is transformed into a free filtering, light, cohesive mass of crystals of magnesium basic carbonate. During this transformation, the precipitate is violently expanded to form the lightest possible, yet bonded, material. This process, being accurately controllable, permits the maximum of strength, uniformity, and light weight, the latter factor naturally greatly influencing the insulation value.

This method of manufacture and process translated into the finished product, including its content of long fibre asbestos, produces a material capable of extremely smooth milling, which means a perfect pipe fit and freedom from voids. This freedom from voids promotes unusually good overall strength.

The 85 per cent Magnesia Sectional Pipe Insulation is made in

sections 3 feet long in the following thicknesses: Standard thick; 1½ inches thick; 2 inches thick; double standard (broken joint) thick; and 3 inches (broken joint) thick.

Each section is furnished with canvas jacket and brass lacquered bands. For pipe sizes up to and including 10-inch diameters the sections are split longitudinally, and for larger pipes curved segments or blocks are provided.

If so desired, R-W 85 per cent Magnesia Pipe Covering can be furnished with a heavier than standard canvas jacket, attached at the factory, ready for use on the job. Also for pipe covering to be exposed to outside conditions, or for underground work, when requested, a weather-proof jacket is applied, furnished with extra collars for covering the end seams. Copper wire and asphalt lap-cement can also be supplied.

When referring to the term "standard thick" and "double standard thick" as they apply to 85 per cent Magnesia Pipe Insulation the following table gives the actual thicknesses:

Pipe Size Inches	Standard Thick Inches	Double Standard Thick Inches	Pipe Size Inches	Standard Thick Inches	Double Standard Thick Inches	Pipe Size Inches	Standard Thick Inches	Double Standard Thick Inches
			3½			10		2½
			4			12		3
1			4½			14		3
1¼			5			16		3
1½			6			18		3
2			7			20		
2½			8			24		
			9			30		

Recommended Thicknesses for 85 Per Cent Magnesia Pipe Coverings

Temperature Degrees F.	Condition or Steam Pressure	Recommended Thickness		
		Pipe Sizes Up to 2 Inches	Pipe Sizes 2 Inches to 4 Inches	Pipe Sizes 4 Inches and Over
Up to 212	Hot Water	Standard	Standard	Standard
212–267	0-25 pounds	Standard	Standard	Standard
267–338	25-100 pounds	Standard	Standard	1½-inch
338–388	100-200 pounds	Standard	1½-inch	2-inch
388–500	Low Superheat	1½-inch	2-inch	Dbl. Standard
500–600	Superheat	2-inch	Dbl. Standard	3-inch

The 85 per cent Magnesia Pipe Covering is packed in handy cartons 18⅛x18x36 inches in sizes up to 3-inch pipe size. The following table shows the content of the carton and the approximate gross weights.

Size Inches	Sections	Approx. Gross Wt. in Lbs.	Size Inches	Sections	Approx. Gross Wt. in Lbs.
½	48	100	1½	24	77
¾	40	90	2	16	75
1	34	85	2½	12	62
1¼	27	80	3	9	55

Coefficients will be found in Table 14, Chapter V, and overall coefficients in Chapter VII. Explanations for use of tables and designing thicknesses are given in Chapter VII.

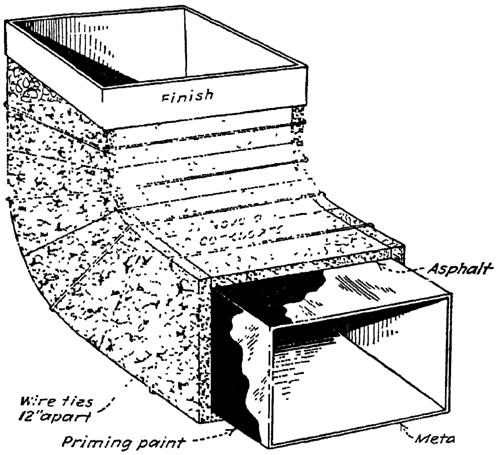


Fig. 23. Cork Insulation for Ducts. See Also Fig. 74

Courtesy of Cork Import Corporation, New York

Duct Insulating Types. *Thermal Insulation.* Fig. 23 shows duct insulating material that is applied on the outside of the duct. The material is supplied in sheets which can easily be cut to required duct size and shape for either square or rectangular ducts. It is made of cork, 1-inch and 1½-inch thicknesses. This insulation is moisture-resistant, and is structurally strong, light in weight, and fire-retardant.

*Duct Vibration Insulation.** The Burgess Acousti-Pad is sound-absorbent but at the same time provides thermal insulation. Thus this medium absorbs sound and resists transmission of heat in that

* Courtesy of the Burgess Battery Company, Chicago, Illinois. Licensed under patents of C. F. Burgess Laboratories, Incorporated.

portion of the duct treated with Acousti-Pad. The medium serves these two purposes but is primarily a sound-absorption insulation for the reason that generally it is not necessary throughout the entire length of a duct. It forms an ideal acoustic lining for ducts because its hard, smooth surface offers the minimum resistance to air flow,

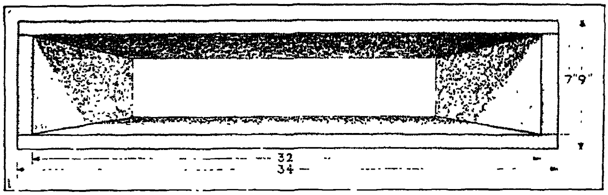


Fig. 24. End View of Duct Insulated with Burgess Acousti-Pad
Courtesy of Burgess Battery Company, Chicago, Illinois. Licensed under Patents of C. F. Burgess Laboratories, Inc.

and its high acoustic efficiency enables it to blot up duct noises as effectively as a blotter blots up ink. The pad does not create an odor when wet. Fig. 24 shows how this pad looks and illustrates the almost 10 per cent perforation of the metal facing which allows nearly 100 per cent of any sound energy striking the surface to pass

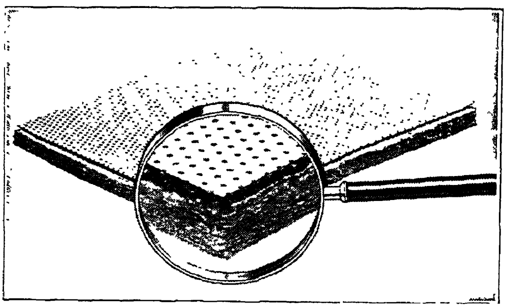


Fig. 25. Enlarged View of Burgess Acousti-Pad
Courtesy of Burgess Battery Company, Chicago, Illinois. Licensed under Patents of C. F. Burgess Laboratories, Inc.

through the holes and dissipate itself in the soft pad of Balsam Wool which forms a part of the Burgess medium.

The insulation is made up as illustrated in Fig. 25. The base is Balsam Wool. The surface is a facing of perforated No. 26 terne plate. This metal facing permits high air velocity without blowing the acoustic material into the air stream. The medium will last as

long as any good metal duct and does not corrode. It may be painted or cleaned without harm to its acoustic function. The perforated metal surface protects the Balsam Wool from fire just as the screen on a Davy lamp prevents the miner's lamp flame from igniting gas. Chemical treatment of Balsam Wool also makes it flame proof.

The effective silencing of noise created by the rush of air which is accomplished by Burgess Acousti-Pad, permits the design of

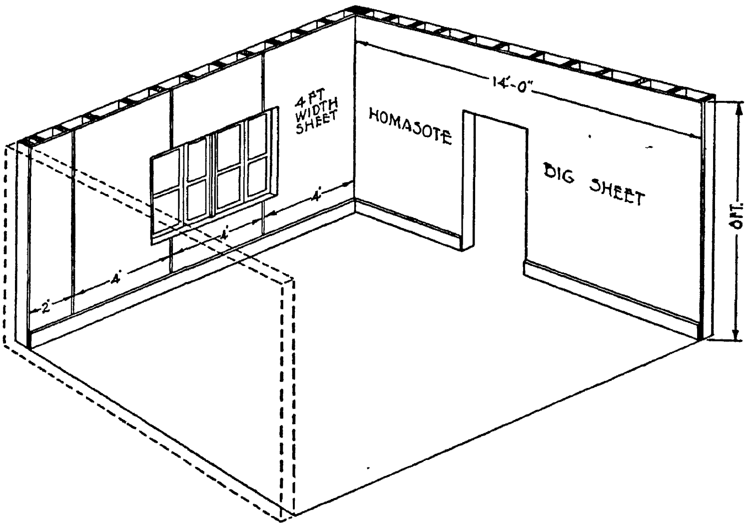


Fig. 26. Rigid Insulation
Courtesy of The Agasote Millboard Company, Trenton, New Jersey

smaller ducts and higher velocities. This saves space and in many cases permits ducts to be run in walls, etc.

Explanation of Decibels (*db*) as well as examples of Burgess Acousti-Pad calculations and tabular matter will be found in Chapter VII.

Rigid Type Sheathing. *Armstrong's Temlok Insulating Board* is made in full ½-inch and full 1-inch thicknesses. It is furnished in boards 4 feet wide by 6, 7, 8, 9, 10 and 12 feet long. When used as sheathing, Temlok Insulating Board is applied in the same manner as ordinary wood sheathing. However, Temlok does much more than merely replace wood sheathing; it insulates against heat and cold. Thus it insures comfort and cuts fuel bills.

Any type of exterior finish—wood, shingles, stucco, or brick or stone veneer—can be applied over the Temlok. Because it is structurally strong and rigid, Temlok adds strength to any structure, in addition to being of high insulating value.

Temlok is furnished in rigid boards and is easily sawed and nailed into place to provide continuous sheathing.

Homasote, Fig. 26, is a combination insulation and structural material in substantial board form. It has balance in its component parts of specially selected wood and other fibres uniformly united in a process that meshes and binds them together securely and permanently.

It is an all-purpose board, used extensively indoors and out. It is weatherproof, repelling moisture and dampness. It resists air infiltration and is a sound deadener. It possesses physical properties which make it an unusually effective insulator. To provide these qualities, each individual fibre is chemically treated and coated before being formed into a board. Such processing has been found desirable because insulation value decreases rapidly when moisture enters.

It is not contended that Homasote is fireproof, but the resistance which it offers to fire and the fact that it does not readily carry a flame, afford considerable protection.

Homasote is a homogeneous board, and has no layers to separate. It averages sixteen ounces per square foot and has 33 to 56 per cent more material than any ½-inch fibre board generally known in the insulation field. It has less breakage waste because it is not brittle. Breakage in ordinary transit or application need not be figured on.

Homasote insulation is $\frac{15}{32}$ inch in thickness and is furnished in large-sized sheets 8x14, 8x12, 8x10, 6x12 feet, and the usual standard sizes 4x14, 4x12, 4x10, 4x9, and 4x8 feet.

Other types of Homasote insulation are: Homasote Type MN, a fire resistant insulating board, from ½ inch to 4 inches in thickness; Homasote Type SP for bad moisture conditions such as found in milk houses and dairies; Homasote Type IP, a fire resistant insulating board which is stronger than Type MN; Homasote Type IP-SP, a fire resistant insulating board for bad moisture conditions.

Another brand of rigid type insulation which has a few somewhat different features is *Insulite.* Insulite Structural Insulation is

made from tough, durable fibres of northern woods. The wood is reduced to fibre by a cold grinding process which assures the retention not alone of natural protective gums inherent in the wood and the full strength of the fibre, but the natural light color of fresh wood as well. The fibres are first subjected to a chemical treatment which renders the finished product moisture-resistant. The formation of the fibre into structural sheets is accomplished by a felting

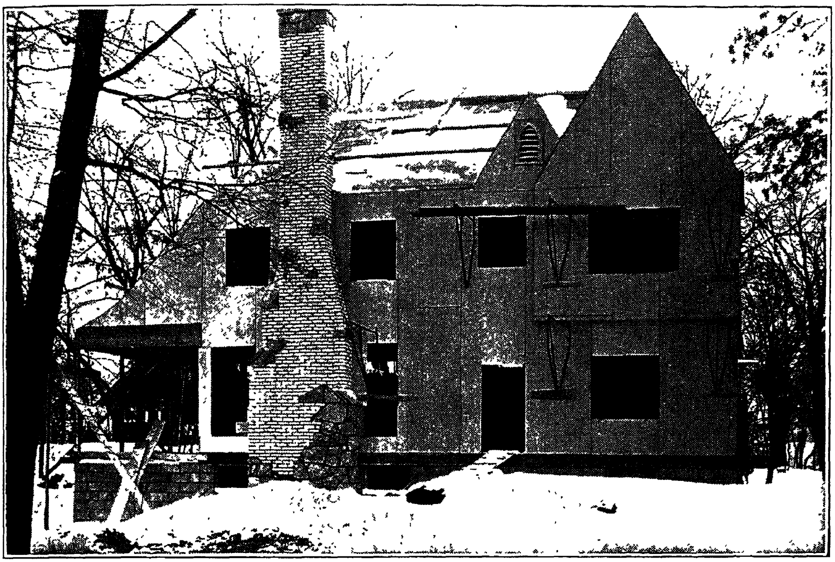


Fig. 27. Rigid Insulating Sheathing
Courtesy of The Insulite Company, Minneapolis, Minnesota

process developed to give maximum strength and heat resistance through the interlacing of the fibre, which seals in millions of minute air cells. (See explanation of Air Cells in Chapter II.) Fig. 27 illustrates this type of insulating sheathing.

These products are protected against damage by termites, rot, and fungi, by a treatment which is colorless and contains nothing that would be injurious to animal or human life.

Building boards are square edged, of standard composition and density. The ½ and ¾-inch thicknesses are homogeneous; 1-inch thickness is laminated, that is, two ½-inch thicknesses are glued.

They are used as insulating structural sheathing and roof board-

ing, exterior and interior wall and ceiling finish, and for sound deadening. Sizes are 4 feet by 5, 6, 7, 8, 9, 10 and 12 feet. They are made ½, ¾, and 1 inch thick in burlap and fine surfaces.

Graylite Building Boards are square edged, of standard composition and density and of a grayish brown color. They are used as insulating structural sheathing and roof boarding, exterior and interior wall finish, and for sound deadening.

Sizes are 4 feet by 5, 6, 7, 8, 9, 10 and 12 feet and 6 feet by 8 and 12 feet. They are made ½, ¾, and 1 inch thick in burlap and fine surfaces.

Bildrite Sheathing is an insulation board of special composition with increased density, furnished in the thickness usually employed for sheathing purposes, 25/32 inch. It is manufactured under an exclusive process incorporating an integral asphalt treatment which gives the product a grayish brown color, increased strength, and added resistance to moisture absorption. It is a highly efficient insulating structural sheathing and insulating roof boarding.

Sizes are 4 feet by 8, 8½, 9, 9½, 10 and 12 feet. It is made 25/32 inch thick, is of homogeneous composition, and is furnished in burlap and fine screen surface textures. Each sheet is marked on the fine screen surface to indicate proper nail spacing.

Another brand of this type of insulation called Celotex is manufactured from corn or cane stalks. These stalks contain long, tough fibres which, when conditioned and interlaced, cling together with great tenacity. These fibres contain millions of air cells which form the insulating medium.

Celotex Sheathing is available in the following dimensions: ½, ¾, and 1 inch thick and in sizes 4 feet by 4, 5, 6, 7, 8, 8½, 9, 9½, 10 and 12 feet.

Besides providing excellent insulation such types of sheathing, when used in place of wood sheathing, as shown in Fig. 27, give more strength than wood insofar as the stiffening effect is concerned. Such insulation is used in large pieces and thus provides the necessary reinforcement to resist distortion, which wood sheathing lacks. This accounts for the fact that there is less trouble with plaster cracking in structures where it is used.

These insulations can be painted or left plain and can generally be secured in either rough or smooth surfaces. Siding or shingles

can be applied directly over these insulating boards or furring can be done first. The edges of the boards are generally beveled or constructed in some lock-joint manner. Coefficients are found in Tables 2 and 14.

Rigid Type Lath. Both Insulite and Celotex manufacture a

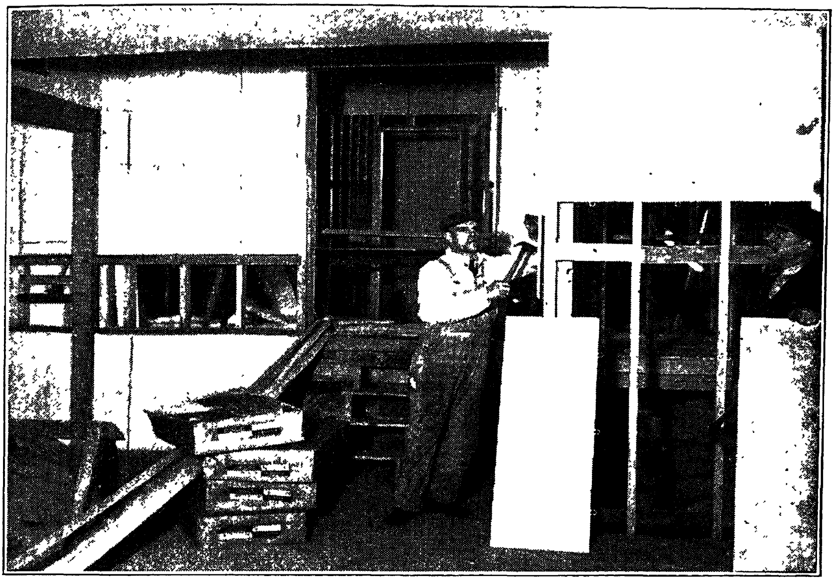


Fig. 28. Lok-Joint Insulation Used for Plaster Backing
Courtesy of The Insulite Company, Minneapolis, Minnesota

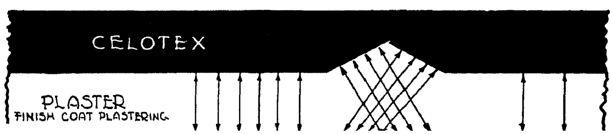


Fig. 29. Celotex Lath Showing Joint
Courtesy of The Celotex Company, Chicago, Illinois

board to be used in place of metal or wood lath and which has the same insulating effect as the sheathing types. See Figs. 28 and 29.

Insulite Lok-Joint Laths are fabricated from boards of standard composition and density, long edges ship-lapped to prevent air infiltration and maintain continuity of insulation. The ½ and ¾-inch thicknesses are homogeneous. 1-inch thickness is laminated

(two ½-inch thicknesses stapled). Galvanized wire "loks," spaced midway between framing supports 16 inches on center, on bottom edge of each unit, which reinforce the unsupported horizontal joint and minimize yielding under trowel pressure during the plastering operation. These "loks" also serve as plaster grounds assuring not less than ¼-inch thickness of plaster for first coat.

Celotex lath are used as an interior insulating plaster base, have beveled edges and ship-lapped joints which reinforce plaster against cracking and provide a continuous sheet of insulation behind the plaster. ½, ¾, and 1 inch thick, 18x48 inches, bundled. Furnished in burlap finish—a surface to which plaster will adhere.

Tests made to determine the bond of plaster to Celotex indicate that plaster attains a bond or holding power to Celotex of 1000 pounds per square foot. This is a stronger bond than is attained where plaster is applied over wood lath and many other types of plaster base. Fig. 29 shows such lath. Coefficients are in Table 2.

Temlok insulating lath, for use as plaster base, is supplied in boards 18x48 inches, with grooved edges on four sides and ship-lapped long edges. It is made in three solid thicknesses, ½, 1, and 1½-inch. It provides an ideal plaster base, gripping plaster firmly and forming a permanent bond. It guards plaster against the cracks which disfigure the finished appearance of the interior of a residence, and unsightly lath marks are eliminated. Temlok replaces the wood and metal lath ordinarily used.

Rigid Type Plank. *Insulite Plank* (Standard and Graylite) is fabricated from both the Standard and Graylite board into several widths with V-W or B-B joints on the long edges. It may be obtained either with or without a bead which runs parallel to the long edges in addition to the V-groove which is provided at all joints. It is an insulating interior wall finish and is used either vertically or horizontally to provide a random plank effect. It can be left natural, stained, or painted.

Made 6, 8, 10, 12, and 16 inches in width and 6, 7, 8, 9, 10, and 12 feet in length, and ½, ¾, and 1 inch thick with either B-B or V-W joint, with or without bead, and choice of standard light color or Graylite. Ends cut square. Coefficients can be found in Tables 2 and 14.

Celotex insulating planks are made ¾ inch thick, 18 inches wide

by 8 feet long. It is furnished in two types, Type E with ship-lapped joint, Type F with tongue and groove joint.

Rigid Type Roofing. *Insulite Asphalted Roof Insulation* is fabricated from sheets of standard composition and density in which is included asphalt uniformly distributed through the board. Meets established thermal insulation efficiencies for roof insulation products. It is used as insulation over various types of roof decks under built-up finished roofing.

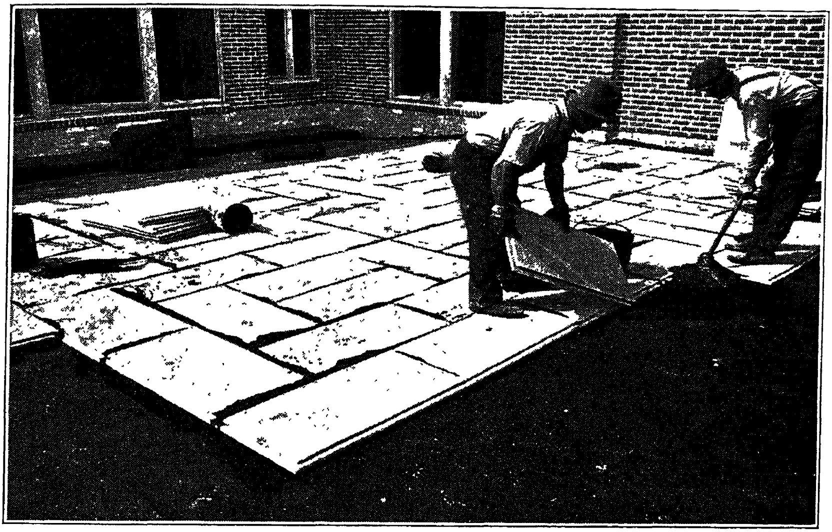


Fig. 30. Roof Insulation
Courtesy of The Insulite Company, Minneapolis, Minnesota

Made in 22x47-inch size. Homogeneous with square edge, ½ inch thick. Homogeneous with either square or offset edges, 1 inch thick. Stitched or cemented with either square or offset edges, 1½ and 2 inches thick.

Insulite Standard Roof Insulation is fabricated from boards of standard composition and density. Thicknesses over 1 inch are formed by stitching with heavy wire staples or cementing with a highly moisture-resistant adhesive, two or more layers of homogeneous standard material together. The 1, 1½ and 2-inch thicknesses can be provided with the original Insulite "offset" feature. This feature consists of a ship-lap on all four edges which provides

heat sealing of joints (continuity of insulation). It is used as insulation over various types of roof decks under built-up finished roofing.

Made 22x47 inches. Homogeneous with square edge, ½ inch thick. Homogeneous with either square or offset edges, 1 inch thick. Stitched or cemented with either square or offset edges, 1½ and 2

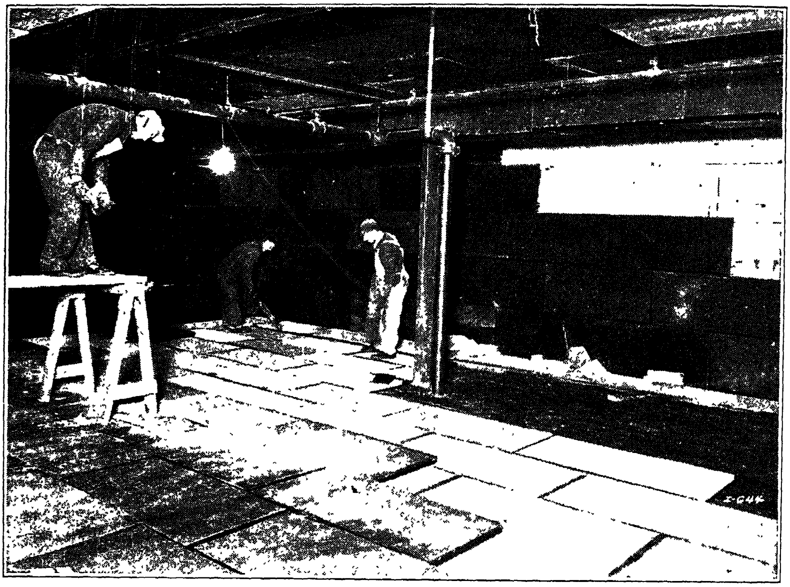


Fig. 31. Cold Storage Insulation
Courtesy of The Insulite Company, Minneapolis, Minnesota

inches thick. See Fig. 30 for an example of such type of insulation. Coefficients can be found in Tables 2 and 14.

Insulite Cold Storage Insulation. This is fabricated from special low density board of standard Insulite composition. Various thicknesses are accomplished by lamination (gluing) of standard thicknesses. Blocks are square edged. Insulite Low Density Insulation has an average conductivity of .28 B.t.u. per square foot, per inch thick, per hour, per degree F., with a density which averages approximately 11½ pounds.

It is designed for insulating floors, walls and ceilings of ice manufacturing plants, cold storage plants, etc., and comes in 6, 9, 12,

18, and 24 inches by 36 inches; 12, 18, and 24 inches by 18 inches; 24x24 inches, 12x48, and 24x48 inches.

Sheets are 1, 1½, 2, 3, and 4 inches thick. Fig. 31 shows this form of insulation. Coefficients can be found in Tables 2 and 14.

Insulite Tile (Standard and Graylite). This type is fabricated from boards of standard composition and density. On finished surfaces all four edges are neatly beveled. Available in two types of

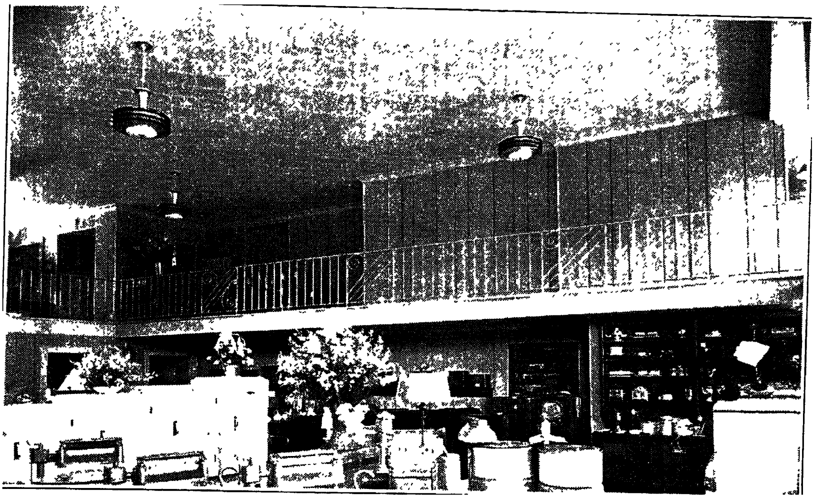


Fig. 32. Small Insulating Tile
Courtesy of The Insulite Company, Minneapolis, Minnesota

joints, V-W and B-B. Tile can be furnished in two distinctive colors—standard, light color; Graylite, grayish brown.

It is used as an insulating interior wall and ceiling finish, secured over plaster or similar finished surfaces with cement or/and brads or secured to structural framing or furring, except where one or the other is specified. In natural or stained finish it is an excellent acoustical absorbent. It comes ½, ¾, and 1 inch thick in burlap and fine surfaces.

In the V-W type, the V-shaped interlocking joint is symmetrical or at about the center line of the tile, making it reversible so that either surface may be exposed. Sizes in this type are 6x6 inches, 6x12, 8x8, 8x16, 12x12, 12x24, 16x16, and 24x24 inches.

In type B-B, the beveled and butt joint is all around each unit.

Sizes in this type are 6x6 inches, 6x12, 8x8, 8x16, 12x12, 12x24, 16x16, and 24x24 inches.

Fig. 32 shows small tile. This type of insulation comes in a variety of shapes and sizes for decorative as well as insulating effect. Coefficients can be found in Tables 2 and 14.

Miscellaneous Rigid Types. *Insulite Termite Board.* Furnished in sizes 4 feet by 6 to 12 feet. Thicknesses of ½ and 1 inch. Termite board, while manufactured specifically for use in termite infested districts, is suited for use in any type of construction. It has high tensile strength, low water absorption, and a pleasing surface finish. Termite board is different from usual materials treated for similar uses in that the termite repellent materials used in termite board will not evaporate or leach out. This is a necessary characteristic of any product used in termite infested districts where exceptionally high temperatures and humidities prevail.

Insulite Fireproofed Board. Furnished in sizes 4 feet by 6 to 12 feet, ½ inch thick. Material is Insulite building board covered on both sides with pure asbestos sheets cemented with fireproof cement. Is adaptable to garages, airplane hangars, basements, and other places where good fire-resisting qualities together with high insulating efficiency are desirable. Extremely light in weight, weighing less than 1000 pounds per thousand square feet ½ inch thick.

Insulite Wall Board. Furnished in sizes 4 feet by 6 to 12 feet; 5⁄16 inch thick. Material is Insulite covered on both sides with high quality kraft paper. To increase the versatility of this product, clear color kraft paper is applied on one surface with a mottled, decorative "oatmeal" finish kraft paper on the opposite surface. Insulite wall board combines the advantages of ordinary wall boards with insulation and sound deadening.

Insulite Fireproofed Wall Board. Furnished in sizes 4 feet by 6 to 12 feet; 5⁄16 inch thick. Material is Insulite building board covered on both sides with pure asbestos sheets cemented with fireproof cement. Insulite fireproofed wall board is a companion product to Insulite ½-inch fireproofed board, adaptable to light wall and partition work where, in addition to some insulation and sound deadening, resistance to fire is essential or desirable. Coefficients can be found in Tables 2 and 14.

Ornamental Acoustic Insulation. This type of insulation can

serve as an actual insulation medium and at the same time as ornamentation. See Fig. 33.

Cane Fibre Tile Acousti-Insulation. Acousti-Celotex cane fibre tile is a rigid block made of felted cane fibres perforated with 441 holes per square foot to increase the sound absorbing efficiency. Tile blocks are finished complete at the factory so that efficiency of

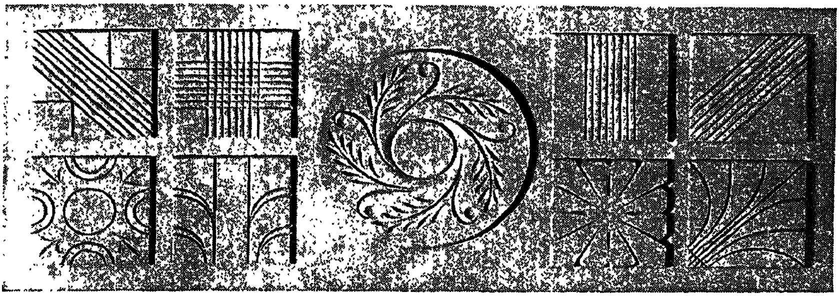


Fig. 33. Ornamental Insulation
Courtesy of The Celotex Company, Chicago, Illinois

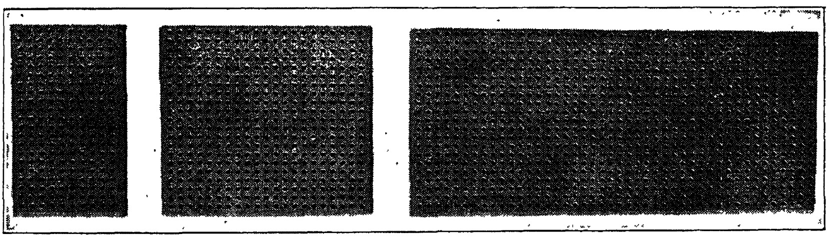


Fig. 34. Acousti-Tile
Courtesy of The Celotex Company, Chicago, Illinois

the installation is not dependent upon the precision of the installing mechanics. The tile is regularly made in 6x12, 12x12, and 12x24-inch sizes. Fig. 34 shows several sizes of this insulation. The material varies in thickness from ⅝ to 1¾ inch.

Akoustolith. A somewhat different type of acousti-insulation is an artificial stone called Akoustolith. It has a sound-absorbing value thought to be greater than any other masonry material. See Fig. 35.

Owing to its light weight and facility of manufacture Akoustolith is easily adapted to plain or elaborate architectural forms. It

is used in tile form on walls, ceilings, arches, vaults, and other architectural forms of a constructive nature. In ashlar form it has been used considerably by architects on sidewalls in lieu of stone work and has been successful in meeting their requirements.

Akoustolith is manufactured in any size from the smaller tile

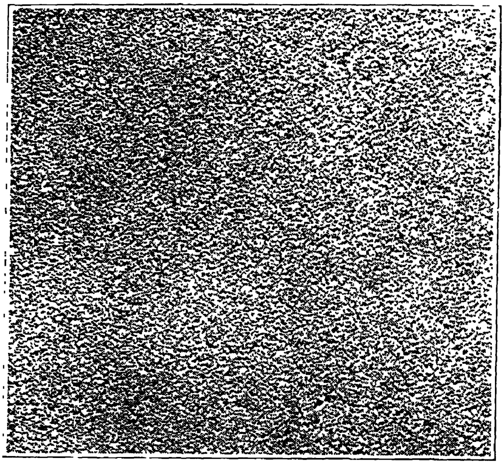


Fig. 35. Akoustolith Insulation
Courtesy of R. Guastavino Company, Boston, Massachusetts

dimensions, 3x6 inches, 4x8, 5x10, 6x12, and 8x16 inches, usually about 1 inch thick and for this thickness weighs about 4 pounds per square foot. This light weight permits Akoustolith to be used in places where heavier material would be impracticable—for instance, ceiling work.

For wall ashlar, Akoustolith can be made in sizes up to 30x60 inches, from 1½ to 2 inches thick depending on size. It can also be moulded or cast in the usual architectural forms. The distance from the backing to the finish face of Akoustolith will vary from 1½ inches for the smaller tile sizes to 3 inches for the larger ashlar sizes.

In addition to the types of specially made acousti-insulation, many of the standard types of insulation such as rigid boards, wool, and blankets are used for sound control work. This is explained by Tables 35, 36, and 37 of Chapter VII. All coefficients can be found in Table 2 in Chapter V.

Hair-Blanket Insulation. Fig. 36 shows Ozite insulation which is made of 100 per cent hair from the hides of cattle. Ozite hair is selected, washed, and purified by chemical treatment. It is then carded into bats similar to ordinary rolls of cotton, and laid between sheets of laminated waterproof paper that are exceptionally strong in texture and hard to puncture. This hair blanket and its paper

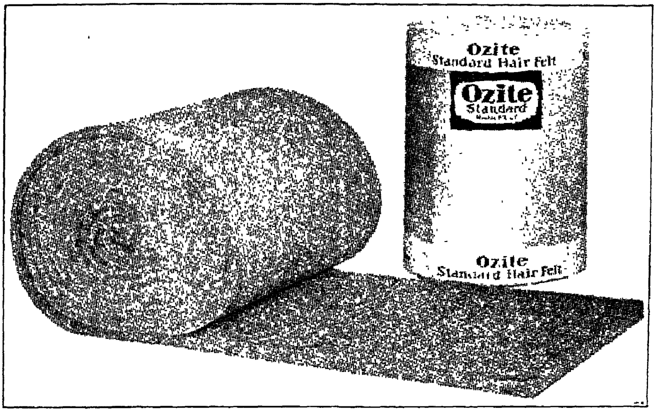


Fig. 36. Hair Blanket Insulation
Courtesy of The American Hair and Felt Company, Chicago, Illinois

jacket are then sewn together on a lockstitch machine with seams 5 inches apart. The stitch holes are sealed to render them air- and moisture-proof.

The result is a thick, flexible blanket that assumes a permanent fluffiness and expands about ⅓ in thickness between every two rows of stitches. This characteristic feature adds extra insulating efficiency which other insulating materials do not offer.

The Ozite laminated paper jacket having an asphalt center assists in repelling moths, vermin, rats, and mice. It is also fire-resisting.

Boiler Insulation. Fig. 37 shows a type of boiler insulation. The use of an asbestos range boiler jacket assures the maximum retention of heat so that the water contained in the boiler stays hot many hours longer than in an uninsulated boiler. The uninsulated boiler might be likened to a stove or radiator which radiates or throws out heat, whereas a boiler covered with a Ruberoid asbestos

range boiler jacket is really like a huge thermos bottle, retaining the heat in the water for hours, as the heat cannot escape through this asbestos insulation.

These jackets are made of built-up layers of corrugated and flat asbestos paper to accurately fit the size of the boiler on which they are to be used. They are flexible and can be applied without any previous experience and with a minimum expense. The out-

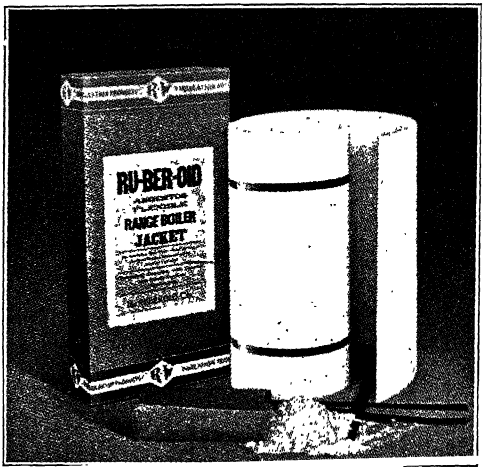


Fig. 37. Jacket Insulation for Boilers
Courtesy of The Ruberoid Company, New York

side jacket is attractive, which permits the use of this insulation in any part of the home.

These flexible range boiler jackets are packed in cartons with complete accessories for application, which include asbestos cement for the insulation of the head and extra wide black bands for holding these jackets on the boiler.

When made for horizontal type boilers, extra asbestos cement is supplied for the insulation of both ends, or solid asbestos cellular disks can be furnished when requested.

The following table shows the sizes in which these jackets are regularly made for the various boiler capacities. See Fig. 37.

30-gallon jacket packed in carton 17x6x36¼ inches, weighs 22 pounds.

Standard Size Jackets and Capacity of Range Boilers

Jackets Inche	Boilers Gallons	Jackets Inches	Boilers Gallons	Jackets Inches	Boilers Gallons
12x60	30	12x48	24	24x72	144
14x60	40	14x48	32	30x72	220
16x60	52	16x48	42	24x84	168
18x60	66	20x60	82	30x84	250
12x36	18	22x60	100	24x96	192
14x36	24	24x60	120	30x96	300

40-gallon jacket packed in carton 19x6x36¼ inches, weighs 25 pounds.

No coefficients are necessary for this insulation. It is designed from such information as shown above.

Plastic Type. *Eagle Super "66" Plastic Insulation* is designed for application on practically any form of heat producing or transferring equipment, where temperature of the surface to be insulated does not exceed 1800°F. Because it is a plastic product, it overcomes many of the serious disadvantages inherent in the more common types of insulating materials, and at the same time offers features resulting from the unique and valuable products entering into its composition. A careful study of the following descriptive data will be well worth while to any engineer interested in the latest development in efficient heat insulation.

In the development of Eagle Super "66," the primary objective of manufacturing has been to produce a plastic insulation which would embody, so far as possible, the unique properties of insulating wool without sacrificing other important and necessary properties in plastic insulation, such as adhesive strength, structural strength, and adaptability.

The most important component of Eagle Super "66" is Eagle insulating wool. This wool is nodulated into small pellets, rolled to uniform size and correct tightness and density. Each pellet is in reality a spongy mass comprising countless dead-air cells. Hence comes the term *springy ball,* an expression accurately describing the physical structure of the insulating element.

The outstanding function of these springy balls is to provide heat-saving efficiency. They are uniform in size and correct in density. There are no large wads or irregular lumps of wool.

Next, the pellets of Eagle wool are thoroughly mixed with long asbestos fibre through a method which entwines the fibre around

each pellet and interlaces it between them. Following this the pellets are rolled in an especially designed binder so that they become completely coated. See Fig. 38.

Sponge Felt Blocks. Eagle sponge felt blocks and sheets are designed for insulating flat, curved, or irregular surfaces having a

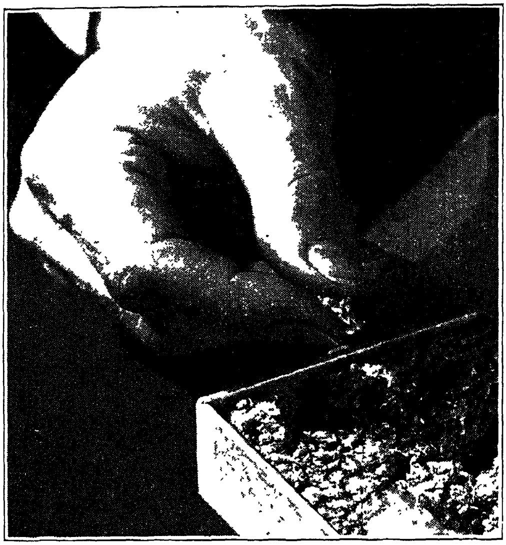


Fig. 38. Plastic Insulation
Courtesy of The Eagle-Picher Company, Cincinnati, Ohio

temperature up to 700°F. These blocks and sheets are especially suitable for applications which are subject to excessive vibration or where it may be necessary to remove and replace the insulation many times.

The blocks and sheets are built up in laminated form from a felt composed of a spongy, cellular material made from asbestos fibre and particles of finely ground sponge. About 40 layers of this felt make 1 inch of thickness. The adhesive strips which bond the laminations run the length of the blocks, allowing great flexibility and easy application to curved surfaces.

These blocks may be used as an outer layer in combination with an inner layer of Eagle Hi-Temp blocks when the surface to be insulated exceeds the maximum temperature recommended for

sponge felt. Such combination construction may be used effectively on temperatures as high as 1600°F. See Fig. 39.

Insulating Brick. A new and distinctive refractory insulating

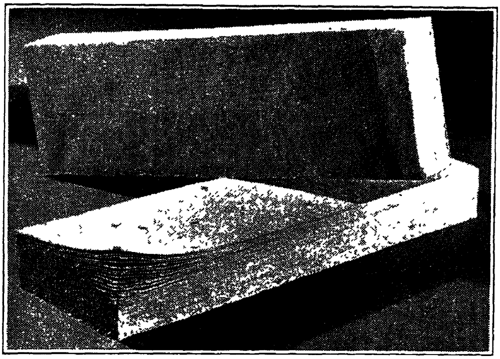


Fig. 39. Sponge-Felt Block Insulation
Courtesy of The Eagle-Picher Company, Cincinnati, Ohio

brick of exceptional strength, the structure of which is interspersed with numerous, well-distributed, fine pores. These pores give the brick its insulating property.

Eagle "BX" will withstand temperature conditions up to

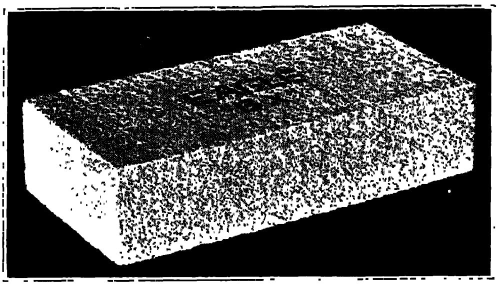


Fig. 40. Insulating Brick
Courtesy of The Eagle-Picher Company, Cincinnati, Ohio

2500°F. Where temperatures of 2400° or 2500°F. are encountered, or where other conditions, such as severe flame impingement make a coating advisable, a protective coating of Eagle "BX" Coating Mortar is recommended. See Fig. 40.

Flash Heat

Wall Thickness Inches	Material	Furnace Temperature in Hours		
		1600°F.	1900°F.	2200°F.
4½	Firebrick	1.72	2.02	2.83
4½	Eagle "BX"	.40	.44	.51
9	Firebrick	2.62	2.97	3.32
9	Eagle "BX"	.58	.63	.73

The heating time in hours required for Eagle "BX" and firebrick to attain flash heat is computed on a basis of rate of heat input into the wall of 5000 B.T.U. per square foot per hour during heat up.

Fireproof Shingles. In a great many cities and towns the building codes prohibit the use of anything but fireproof shingles or roofing material. Many varieties and brands of shingles are available.

Fig. 41 illustrates a very popular type of asbestos shingle made by Johns-Manville Company. The shingles are made of asbestos

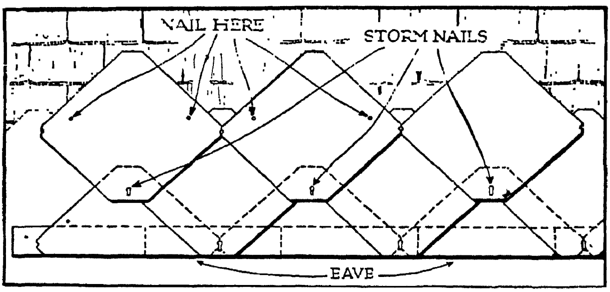


Fig. 41. Hexagon Asbestos Shingles
Courtesy of Johns-Manville Company, New York

fibres and cement and are practically everlasting. This common type of shingle can be laid over an old roof, as shown in Fig. 41, or can be laid on a new roof deck as shown in Fig. 42 where another common type of shingle is used.

Fireproof Asbestos Siding. Fig. 43 illustrates a common type of asbestos shingle to be used as siding. As will be noted the shingles can be put on over old siding, or they can be nailed directly

to sheathing on a new structure. Such shingles are grained so as to resemble cedar (wood) shingles.

All types of asbestos and other fireproof kinds of shingles and

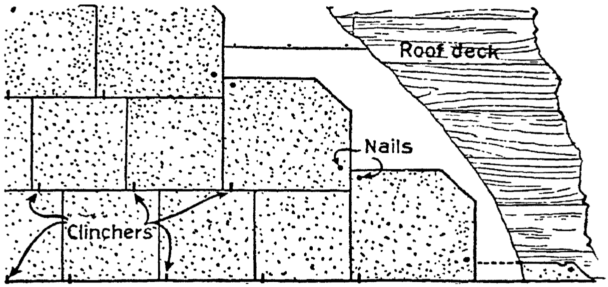


Fig. 42. Dutch Lap Asbestos Shingles

This diagram shows graphically how easily a No. 30 Dutch Lap Roof can be laid. The J-M Clincher securely locks exposed corners with minimum of labor.

Courtesy of Johns-Manville Company, New York

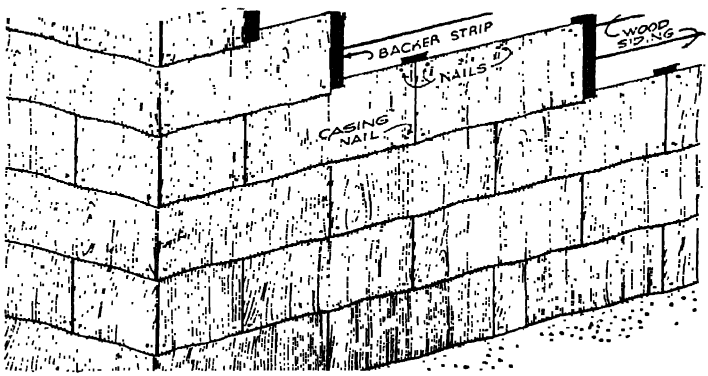


Fig. 43. Cedargrain Siding

Method of re-siding with Cedargrain Shingles. Butts are secured by casing nails. Joints are made watertight and windtight by felt backer strips. On new construction, the entire building should be sheathed with 20 lb. coated asbestos felt, in addition to the felt strips behind the joints.

Courtesy of Johns-Manville Company. New York

siding can be secured in a variety of colors to suit individual conditions.

Interior Finish Type. Some insulations are made more especially for interior finish and trim. Nu-Wood is a typical example. It is processed wood. Clean, new wood is separated into individual fibres

which are assembled under pressure to form a board of many uses, one of which is interior finish.

Nu-Wood interior finish is installed over wall and ceiling surfaces of plaster, masonry, or wood in old construction, or over framing in new construction to take the place of lath and plaster.

It needs no painting or decorating. Its soft shades of tan and its interesting surface texture give Nu-Wood rooms unusual decorative effects. Yet Nu-Wood does more than decorate. It insulates against heat and cold. It hushes noise.

Nu-Wood is made in several pre-decorated units in a variety of sizes. Any required thickness over ½ inch (in multiples of ½ inch) is available. Each unit is provided with edges which experience has shown to be best suited for carefully designed interior finish.

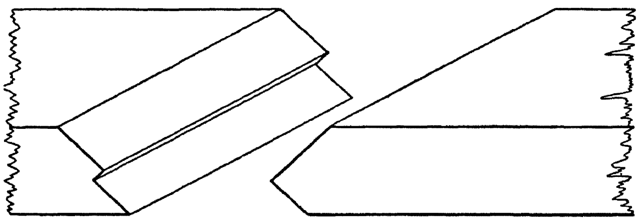


Fig. 44. Bevel-Lap Joint
Courtesy of Wood Conversion Company, St. Paul, Minnesota

Nu-Wood board is a square edged structural insulating board with a soft neutral wood-brown color. It blends harmoniously with any scheme of decoration and furnishings. One side has a smooth screen finish, the other an individual texture.

Nu-Wood board is used on walls and ceilings with moldings of Nu-Wood, wood or metal, as a centerpiece in a field of other Nu-Wood units, or as a border. Sizes—4 feet by 4, 6, 7, 8, 9, 10, and 12 feet. Full ½ inch thick. Thicknesses up to 2 inches.

Nu-Wood bevel-lap tile comes in rectangular tile units. All four edges are provided with the bevel-lap joint (Fig. 44). Available in a harmonizing color range varying from light tan to rich wood-brown. Ivory tile can be furnished when light reflection is an important factor. Sizes—Standard sizes 8x8, 12x12, 12x24, 8x16, 16x16, 16x32, 16x48, 24x24, and 24x48 inches. Special sizes, 6x6, 6x12, 18x32, and 18x48 inches. Thickness—full ½ inch. Other types of Nu-Wood are mentioned in Table 14.

CHAPTER IV

WHERE INSULATION IS USED

In Chapters I and II the reader learned the nature of insulation and something of its physical make-up. In Chapter III various typical kinds of insulation were illustrated and their composition, manufacture, and uses briefly discussed. In this chapter, the use of typical insulations, in general structures, is shown and explained. Not every type or brand of insulation can be discussed, but, as in Chapter III, enough are dealt with to amply explain the general problem of insulation in the phases listed in Chapter II. No preference is implied for any one type of insulation. The trade names used are employed wholly as typical examples of their types.

Frame Residences. A frame residence is assumed as being constructed of wood parts throughout—framing, floors, walls, roofs, etc., only the foundations being made of masonry materials. Such a residence is illustrated by Figs. 125 to 131 inclusive, in Chapter VIII. This type of structure affords perhaps more opportunities for insulation than most other types.

The ordinary frame wall consists of studs, sheathing, siding, lathing, and plaster. There are two general kinds of such framing; Western Framing and Balloon Framing. These are illustrated in Figs. 45 and 46. For the purpose of studying the application of insulation to such framing, cross sections of the various parts will be considered.

Both Western and Balloon framing have outside sheathing, as indicated in Figs. 45 and 46, and both frames are plastered on the inside in exactly the same manner. Fig. 47 shows a cross section of a typical frame outside wall which has no insulation at all. Either metal or wood lath can be assumed. This section is what we would see were we looking down on the wall. Fig. 47 applies equally well to both Western or Balloon framing.

Fig. 48 shows the same wall with insulation applied as noted by specifications on the sketch and by the heavy solid lines. This insulation is the rigid type, such as was illustrated in Chapter III,

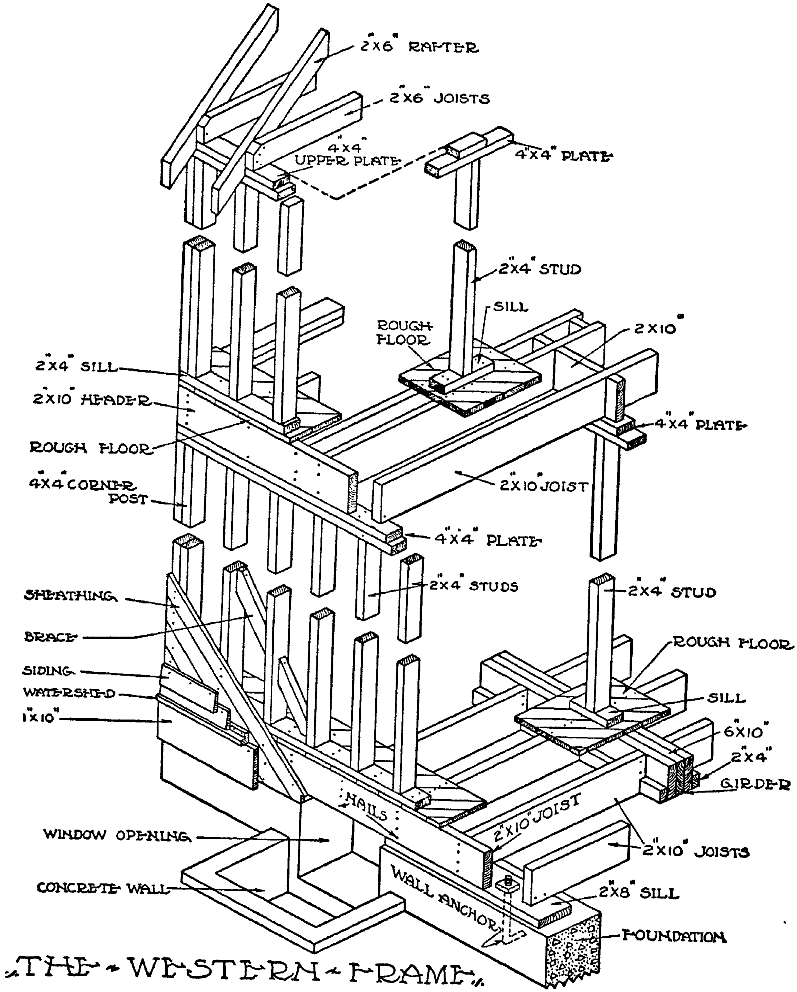


Fig. 45. The Western Frame

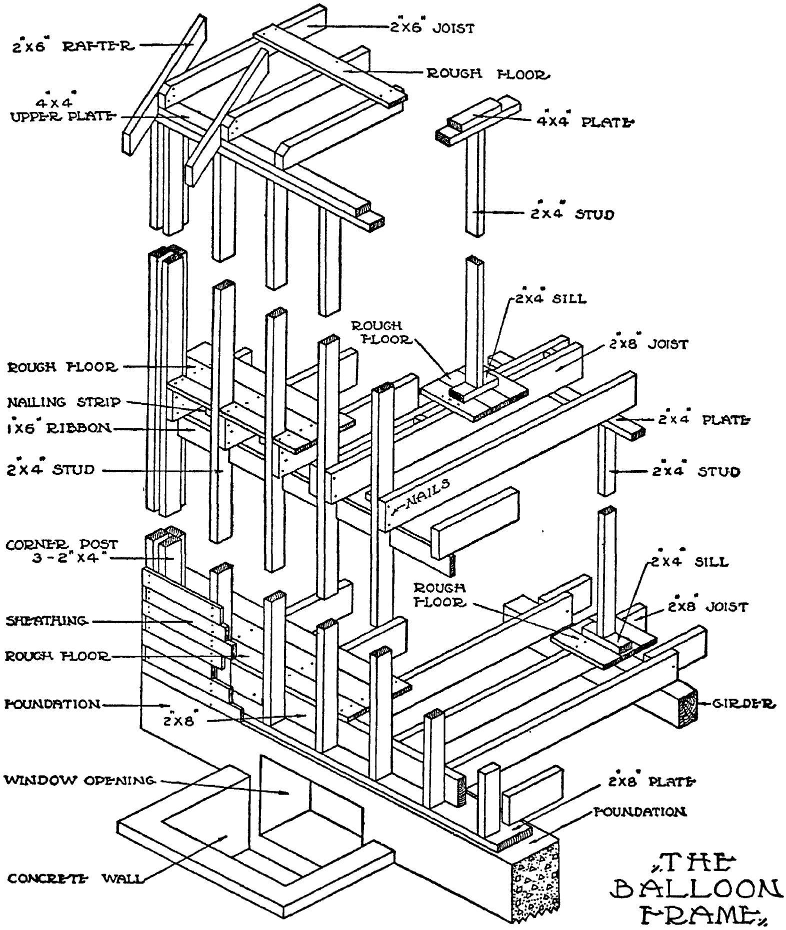


Fig. 46. The Balloon Frame

and is used in place of wood sheathing and laths. The lathing, or plaster backing, was described in Chapter III. The insulation comes in various sized sheets and is applied directly to the studs both as sheathing and plaster backing.

If required, only the sheathing can be of insulation material leaving the lathing of wood, metal, sheet rock, or plaster. Also, many types of insulating plaster backing can be used as lathing and plaster all in one. In such cases wall paper or paint can be applied

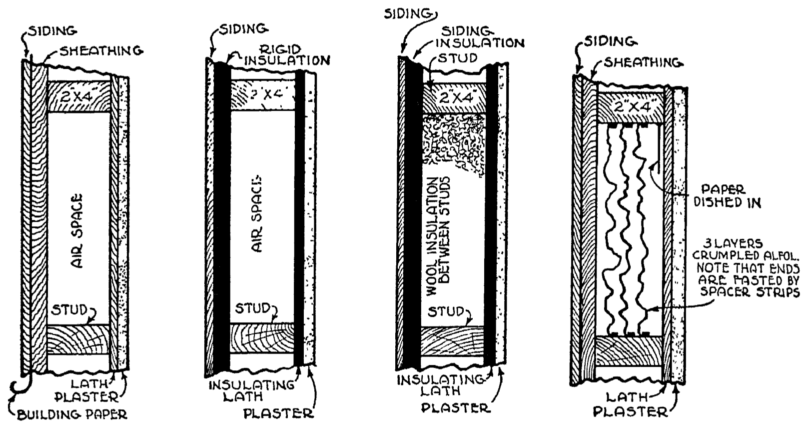


Fig. 47. Fig. 48. Fig. 49. Fig. 50.

Sections of Frame Wall: Uninsulated; with Rigid Insulation in Place of Sheathing and Lath; with 100 Per Cent Use of Rigid and Wool Insulation; and with Aluminum Foil Insulation.

directly to the material. This is especially feasible where the insulating material comes in large sheets, such as Homasote, illustrated in Chapter III. Another alternative would be to have only the plaster backing as insulation material.

Still another insulating method is shown in Fig. 49. Here in addition to insulation used as sheathing and plaster backing we have added wool between the studs in loose fill. This affords almost 100 per cent insulation and is about as much as can be done using these types of insulators. It is more expensive and naturally better than that shown in either Fig. 47 or Fig. 48. If wool is used, either the insulating sheathing or plaster backing or both might be left out.

In Fig. 50 is illustrated an entirely different principle of insulation, namely, the aluminum foil type, described in Chapter III. This

insulation is slightly crumpled, as explained in specifications in Chapter III. As many layers as practical can be used; naturally, three or four layers would be more effective than one layer.

There are many varieties of frame walls in which siding, shingles, clapboards, etc., are used as the exterior surfaces. In some cases where shingles, for example, are used, they are furred out from the sheathing. However, this does not affect the placing of the insulation as explained for Figs. 47 to 50.

Inside partitions can be treated in much the same manner as outside walls. Fig. 51 shows a cross section of a typical partition

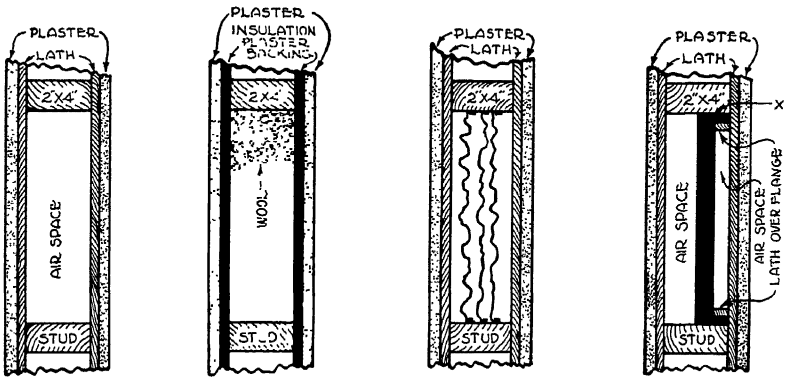


Fig. 51. Fig. 52. Fig. 53. Fig. 54.

Sections of Interior Partitions: Uninsulated; with 100 Per Cent Rigid and Wool Insulation; with Aluminum Foil Insulation; and with Blanket Insulation.

having wood studs, and wood, metal, or board type lath and plaster on both sides. The heavy lines in Fig. 52 indicate the possibility of using rigid plaster backing or lathing of insulating materials on both sides of the partition. If necessary, wool fill may be used, too. Alternatives would be to use no insulator except wool, insulating lath used on only one side of the partition, or wool with insulating lath on only one side of the partition. The choice of method depends on conditions physical and financial, as explained in Chapter VIII.

Fig. 53 illustrates the use of Alfol in a partition. The material is crumpled and fastened into place as in outside walls and the number of layers used depends on degree of insulation required.

In Fig. 54, the heavy black portion illustrates how blankets or

quilt types of insulation are used in walls. The material is nailed to the studs by laths or small section pieces of wood so that it lies up against the stud as shown at X in Fig. 54. The procedure is the

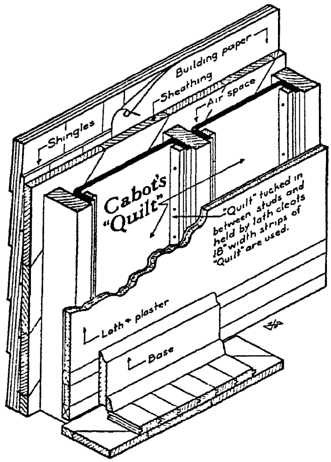


Fig. 55. Isometric View of Frame Wall Showing Application of Quilt Type Insulation

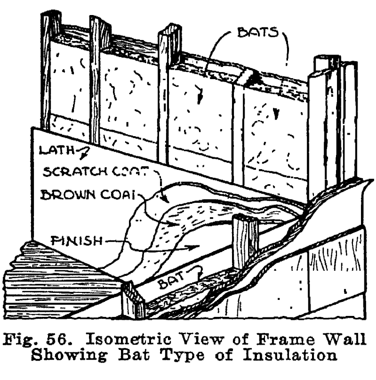


Fig. 56. Isometric View of Frame Wall Showing Bat Type of Insulation

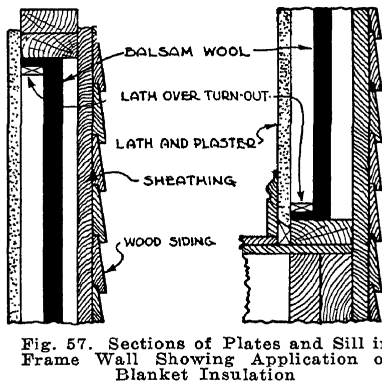


Fig. 57. Sections of Plates and Sill in Frame Wall Showing Application of Blanket Insulation

same for either inside partitions or outside walls. Fig. 55 shows this in perspective to help the reader visualize it.

The bat type of insulation comes in such widths as fit easily between studs which are 16 inches center to center. Fig. 56 shows bats in place in a wall. The placing is the same for either outside

or inside walls. Bats may be used in place of wool in conjunction with rigid types of insulation as shown in Figs. 48 and 52.

Fig. 57 shows how blanket and quilt types of insulation are placed at plates and sills. It is very important to insulate at these points because leaks can do more harm than the rest of the insulated area can correct. When rigid types of insulation are used, the material safely seals, because it replaces sheathing or lath, and as can

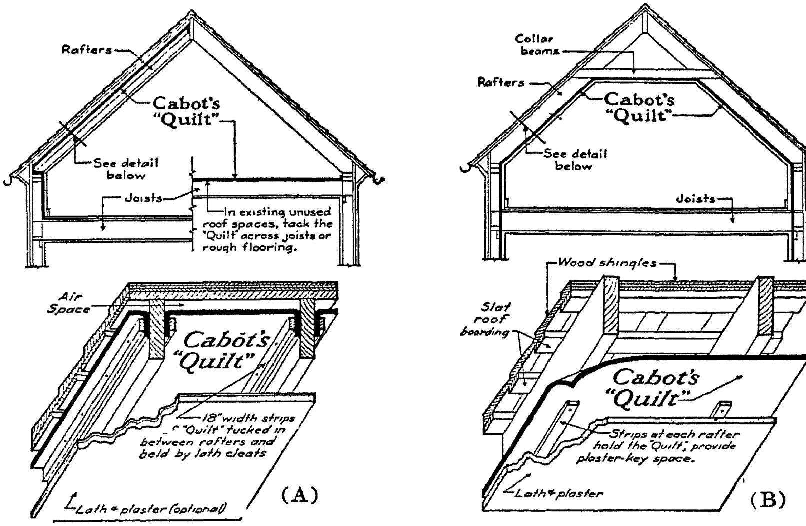


Fig. 58. Roof Sections Showing Application of Quilt Type of Insulation

be seen in Figs. 45 and 46, the sheathing or lathing completely covers all parts of the frame. See Fig. 82A.

Some blanket, quilt, or bat types of insulation are applied somewhat differently than has been thus far explained, but the methods do not vary greatly, so the foregoing discussion and illustrations are sufficient.

Roof insulation is one of the most important insulating jobs in a residence, because an uninsulated roof causes no end of trouble both in winter and summer. Fig. 58 shows two methods whereby the quilt or blanket type of insulation is used. Method (A) shows the material is nailed in place between rafters by laths. Method (B) shows the material is stretched across the rafters, allowing ample overlap, and nailed in place by furring strips. In both cases the

roof boards are put on as usual. Where the roof forms a direct contact with bedrooms, as indicated in Fig. 58 and as is the case in the plans shown in Chapter VIII, plastering will be put on the under or inside of rafters.

Rigid types of insulation are used on roofs as shown in Fig. 59. Type (A) shows uninsulated roofing, and type (B) shows rigid

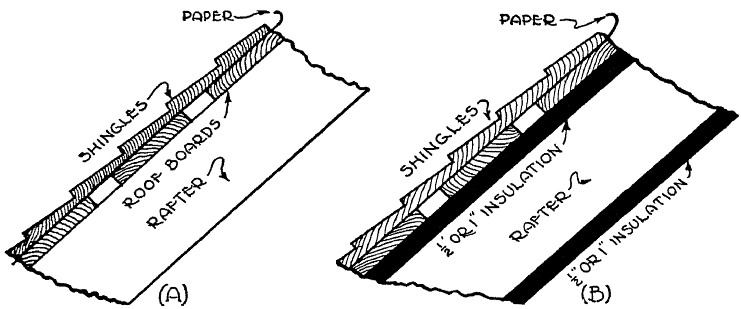


Fig. 59. Roof Section Showing (A) No Insulation and (B) Recommended Rigid Insulation

insulation under shingles and as a plaster base, or merely as a covering for the rafters where no plaster will be applied. An alternative would be to use insulation only under the shingles or only as a plaster base. In the case where the insulation forms the finished surface on which paper or paint can be applied, the insulating material is applied only on the under side of the rafters. In an attic where no finishing or trimming is to be done, rigid insulation could be put under the roof sheathing or boards.

Wool or loose types of insulation can be used in a roof only in cases where the roof comes into contact with bedrooms, and where plaster is being applied to the under or inside of the rafters. In such a case wool could be blown in, as shown in Fig. 49. Special care should be taken to insure the wool completely filling the space. Any vacant space would ruin the effects of the insulation and cause discoloration of ceiling at that point.

Foil type insulation is put between roof rafters in much the same manner as in walls. Fig. 60 shows the details and specifications for its installation in a roof. The foil must be tacked on carefully so that no sagging or pulling away from the rafters is possible.

Larger or heavier types of roof insulation will be explained in a section of this text devoted to roofing of larger buildings.

The reader should keep in mind that many different combinations may be designed for roof insulation, depending on physical

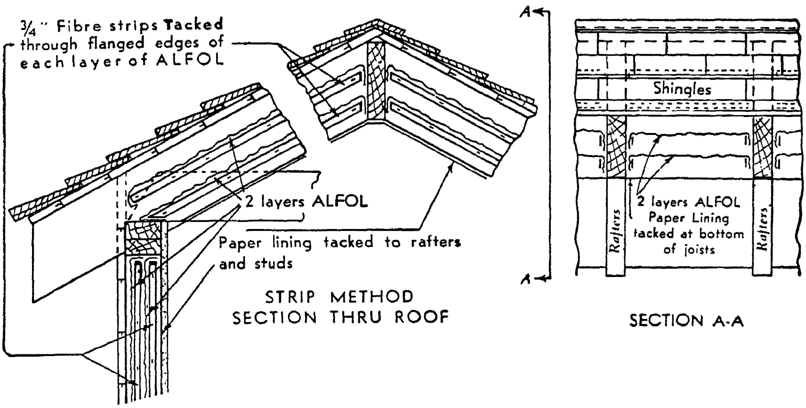


Fig. 60. Roof Sections Showing Applications of Aluminum Foil Insulation
Courtesy of Alfol Company, New York

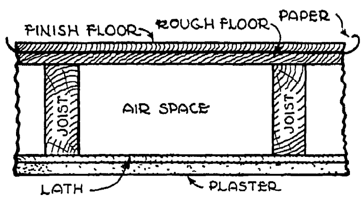


Fig. 61. Section of Uninsulated Floor in Frame House

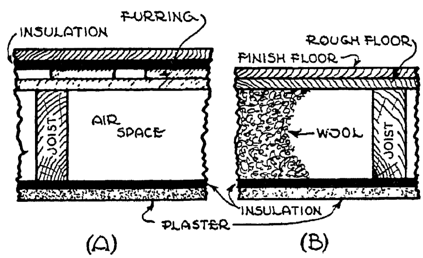


Fig. 62. Section of Floor in Frame House Showing (A) Rigid and (B) Wool Type Insulations

conditions of particular jobs and their requirements, financial status, and the individual opinion of the designer. Enough examples are given here to show the principles.

Fig. 61 shows an uninsulated floor. Rigid insulation is used in floors as shown in Fig. 62. Floors may be insulated in a great many ways by the use of rigid insulation. Fig. 62A shows furring strips put down over the rough flooring and either ½-inch or 1-inch rigid insulation nailed to the furring. Then the finish floor is laid

directly on the insulation. This is for the top side or floor proper on the joists. If there is to be a ceiling, insulation for plaster backing may or may not be used. Another method of insulating the floor and the ceiling is shown at B in Fig. 62. Here wool has been put between the floor and ceiling and insulation used as plaster backing. Wool can be used only where there is a ceiling to hold it in place.

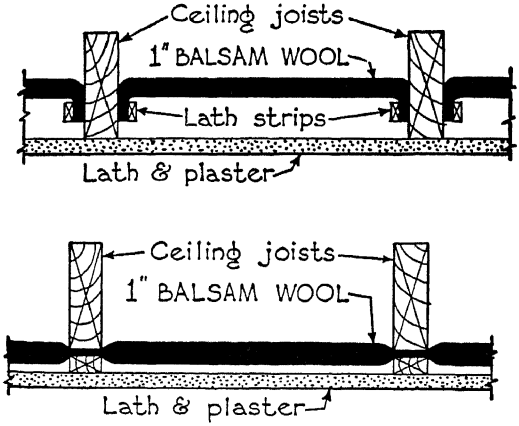


Fig. 63. Sections of Ceilings Showing Application of Quilt or Blanket Type of Insulation

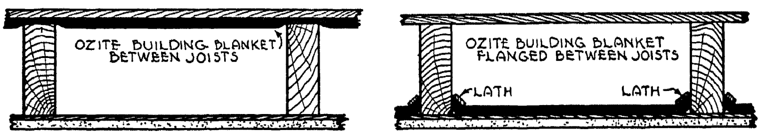


Fig. 64. Sections of Floors Showing Other Methods of Applying Quilt and Blanket Types of Insulation

Rigid insulation in floors over basements or other areas that are not to be finished off must needs be confined to the floor proper. Rough ceilings for basements can be made by using insulation on the under side of joists, thus providing the benefits of insulation.

Quilt or blanket types of insulation can be used between joists in much the same manner as in roofs, especially if a ceiling is to be built. Figs. 63 and 64 show other methods of applying blanket or wool types of insulation to ceilings and floors.

Foil type is used as in walls except that when ceilings are unfinished, a heavy paper or light sheathing should be nailed to the under side of the joists.

In basements, partitions and ceilings can be surfaced with a rigid type of fireproof insulation which serves as a guard against transmission of heat also.

Insulation around windows should fit as snugly as possible to avoid costly infiltration. (Infiltration is explained in Chapter V.) Fig. 65 shows how blanket or quilt types are fitted snugly around

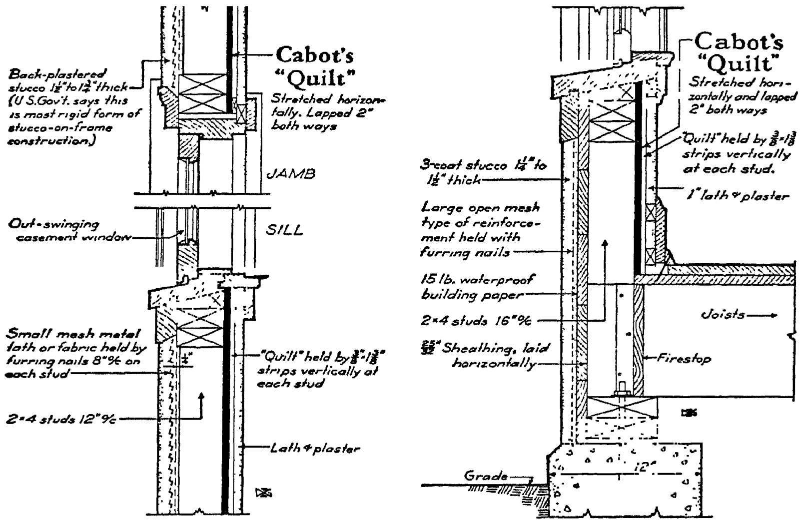


Fig. 65. Window and Sill Sections in House Showing Method of Applying Quilt or Blanket Insulation

windows. Rigid types will naturally fit closely because they take the place of sheathing and lath. See Fig. 82.

Where attic spaces are too small to justify flooring on the joists, the ceilings can be insulated by loose fill, blanket, or quilt types, the thicknesses depending on material and designer.

Dormers, as shown in Fig. 66, need special care in order to assure comfort in interior spaces. Fig. 66 shows quilt or blanket type of insulation in the roof just below the dormer window sill and above the dormer ceiling and running beyond the main ceiling of the interior space. Thus the entire area is protected. Rigid insulation could as well be used, according to explanations for Figs. 59, 58, and 53, or loose wool or blankets could be applied between the ceiling joists or roof joists of the dormer proper. It is possible to

insulate this dormer and the adjacent parts in as many different ways, including aluminum foil type, as have been explained for walls, roofs, floors, and ceilings. If finances permit, dormers such as are shown in Fig. 66, and in the four views of Fig. 135 in Chapter VIII should be thoroughly insulated, using ample blanket or quilt, or combinations of rigid and loose wool insulation. Special care should be taken to see that all roof parts are properly insulated. This can

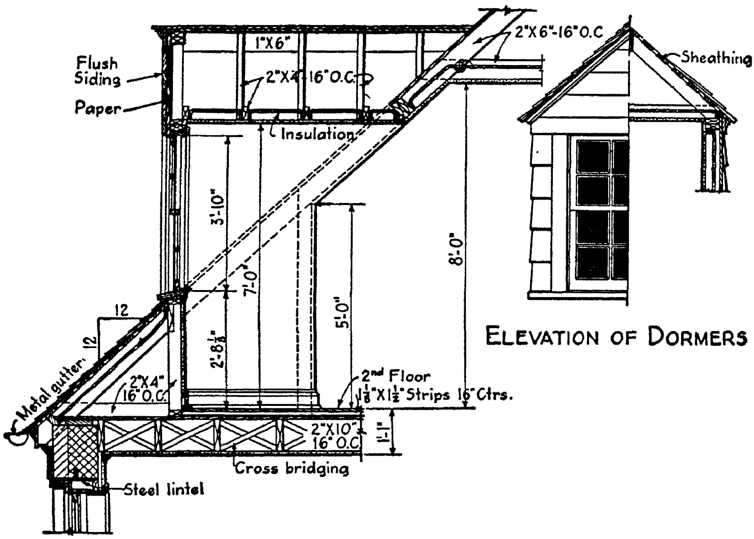


Fig. 66. Section through Dormer Window Showing Method of Insulating

be done only by assuming a certain method of insulation and then calculating heat loss or gain to see if enough or the best method has been chosen.

Cornices are another source of leakage unless properly insulated. Fig. 67 shows what might be called minimum insulation of the quilt or blanket types. The blanket or quilt could well be carried on up the roof between joists to provide even more insulation. Rigid insulations could be used in place of sheathing and lathing, Fig. 48; in place of ceiling lath, Fig. 62; under the shingles, and as a surfacing for attic spaces, Fig. 59; and in floor assembly, Fig. 62. In addition to, in conjunction with, or without the rigid insulation, loose wool

could be used in the wall, over the plaster in the ceiling, and in the roof if the inner side of rafters were sheathed.

Aluminum foil could be used in the walls, Fig. 53; in the roof, Fig. 60; in the ceiling, etc.

Fireproofing frame residences is more a matter of fire retarding than fireproofing because wood will ignite and burn if fire or sufficient

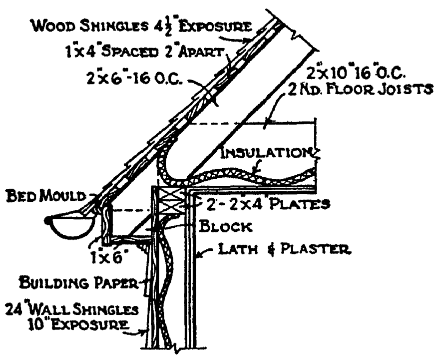


Fig. 67. Section of Cornice Showing Application of Quilt or Blanket Insulation

heat reaches it. These general principles have been explained in Chapter II.

Walls or partitions, ceiling, and stairways leading to the basement can be made fire resistant by installing a fireproof insulating board such as is described in Chapter III and shown in Fig. 68. This will retard the spread of any fire that might originate in the basement.

The next fire stopping means at our disposal, just above the basement level, would be the sills for walls and partitions. The usual methods are shown in Fig. 69. Other points of control are at the cornice, partition bases, chimney, etc. The recommended practices are shown in Fig. 69. In all cases the object is to stop or retard the spread of fire and the equally dangerous heat. If we can seal up walls and partitions, and thus prevent their acting like chimneys during a fire, we have really accomplished something, because every minute a fire is kept from spreading is important, especially in cities where fire-fighting apparatus can be called for aid.

Fireproof shingles, such as those illustrated in Chapter III, are

also a necessity if fire prevention is to be accomplished to the highest possible degree. Such shingles prevent roof fires from sparks caused

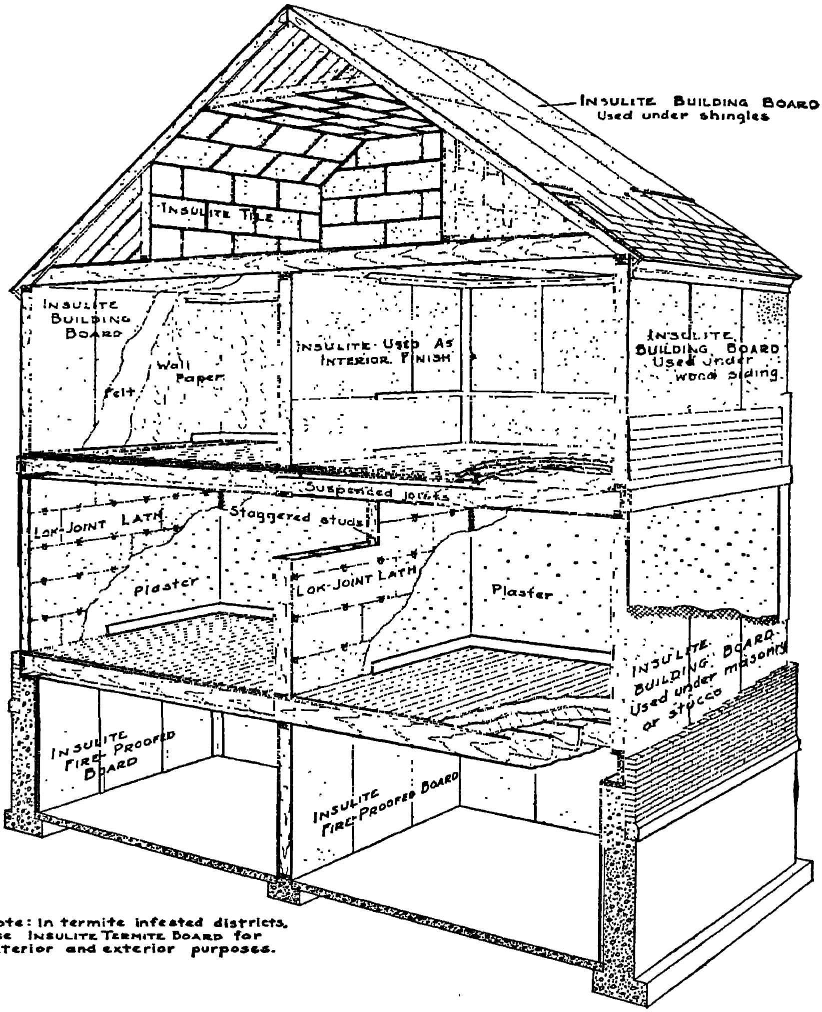


Fig. 68. Section of Frame House Showing a Typical, Recommended 100 Per Cent Application of Insulation
Courtesy of The Insulite Company, Minneapolis, Minnesota

by chimneys burning out and are a protection against flying embers from a fire, perhaps blocks away.

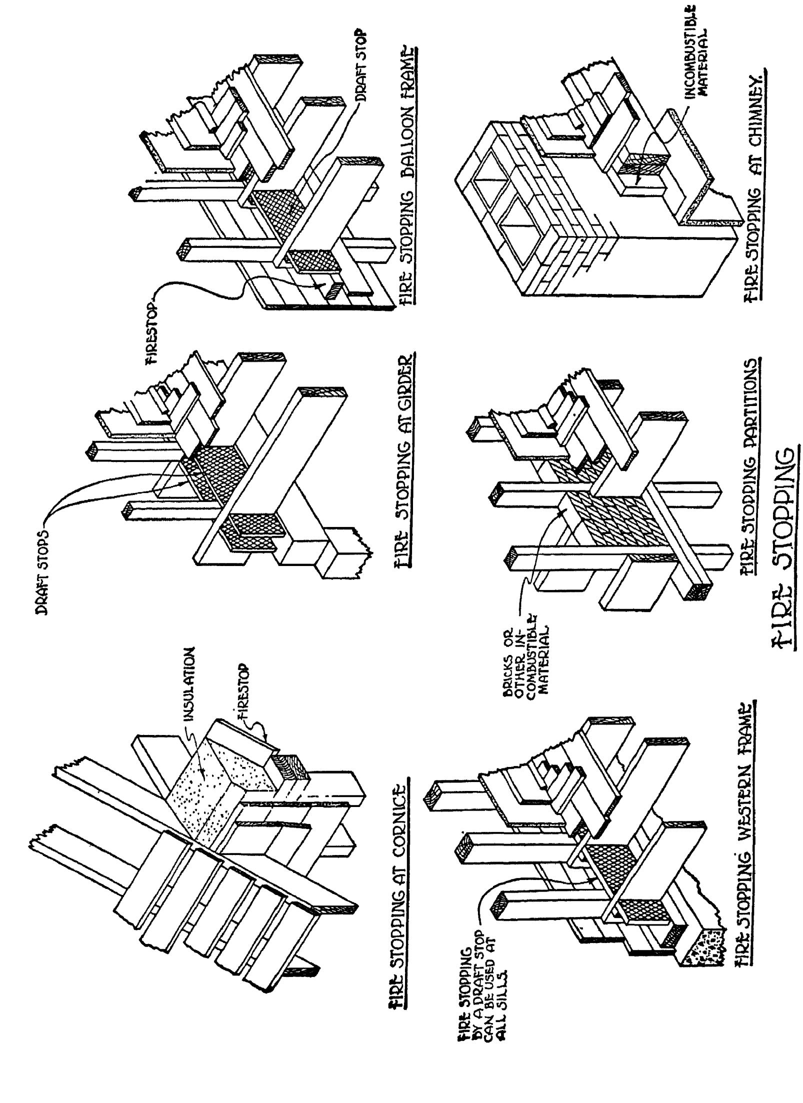


Fig. 69. Typical Fire-Stopping Methods for a Frame House

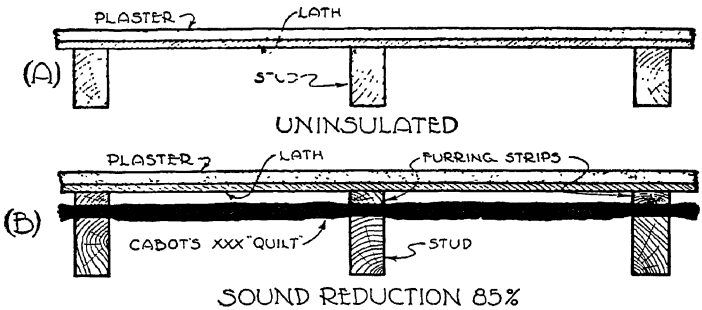


Fig. 70. Sections of Wall Showing Application of Quilt Insulation for Sound Reduction

Courtesy of Samuel Cabot, Incorporated, Boston, Massachusetts

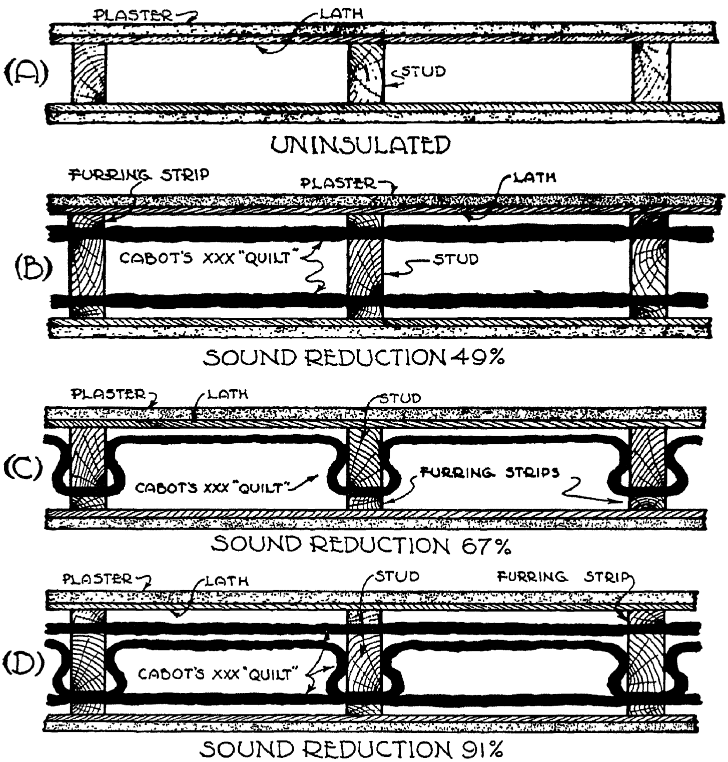


Fig. 71. Sections of Wall Showing Three Methods of Sound Insulation

Courtesy of Samuel Cabot, Incorporated, Boston, Massachusetts

Sound insulation in a frame residence is difficult and expensive to install unless considerable insulation against heat transmission is being used. Many types of insulations have a marked ability to absorb sound, as will be seen in Table 38 of Chapter VII. For example, where blanket types of insulation are used in a wall or partition, considerable sound insulation is also obtained. In Chapter VII will be given examples of sound control design, but here the discussion will concern the location of such insulation in frame residences.

Fig. 70A shows a simple wall or partition having lath and plaster on only one side; Fig. 70B shows a strip of blanket or quilt type of insulation added. This reduces sound transmission by 85 per cent.

Fig. 71A shows an ordinary uninsulated wall or partition with lath and plaster on both sides. Fig. 71B, C, and D show several typical ways of using quilt or blanket insulation to absorb sound. The more sound reduction desired, the more insulation is needed to accomplish it. While serving as a sound insulator the material also prevents transmission of heat.

As explained in Chapter II, sound travels by conduction as well as by air. Therefore, various framing members in a frame residence conduct sound almost as a wire conducts electricity. It stands to reason, therefore, that the studs in a partition such as illustrated in Fig. 71 will conduct sound. To avoid any possibility of such conduction, the studs can be staggered, as shown in Fig. 72A. Then, to further reduce the sound, methods shown in Fig. 72B and C can be used. This becomes costly but is very desirable from the standpoints of both heat transmission and sound reduction.

Fig 73A shows a floor design, uninsulated. Fig. 73B, C, D, and E show methods of insulating a floor. It will be noted that in Fig. 73D the joists support the floor and that false joists support the ceiling.

In cases such as those illustrated in Fig. 72B and C, and 73D the result of staggering the main members (the 2x4 studs and larger joists) is that sound cannot be conducted from one side of the partition to the other because the studs and joists that touch one side do not touch the other side.

In place of flexible types of insulation for walls and floors,

rigid types of insulation could be substituted for the quilt or blanket shown in Figs. 72B and 73D, if the studs or joists are far enough apart to allow a sheet of Insulite (see Chapter III), for example, to be set in place. For instance in Fig. 72B the studs would have to be so placed that a ⅞-inch sheet of Insulite could be put between points *X* and *Y*. This would make the wall thickness greater but

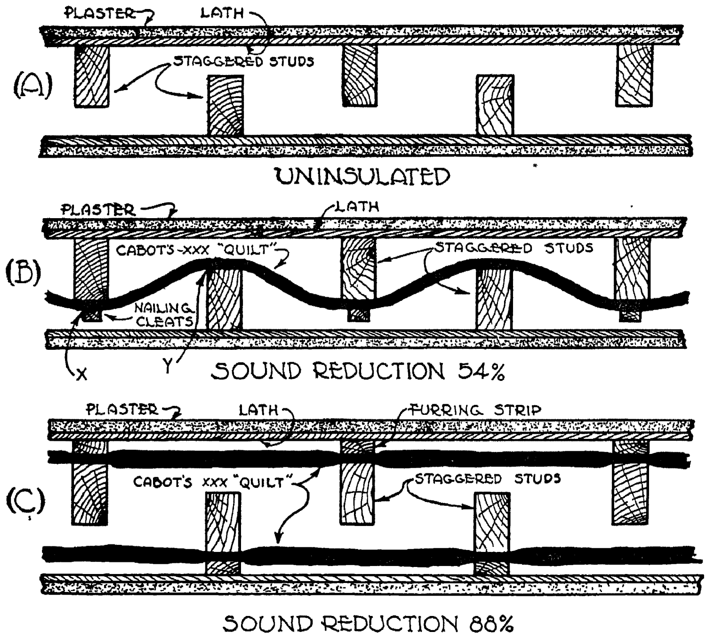


Fig. 72. Sections of Wall Showing Two Methods of Sound Insulation
Courtesy of Samuel Cabot, Incorporated, Boston, Massachusetts

that would be an advantage in case large ducts or pipes were to be carried to an upper floor.

In residences where more than ordinary sound absorption is required, various tiles such as Acousti-Celotex, Akoustolith, etc., can be used on ceilings and sidewalls. Also various decorative mouldings which have sound absorbing qualities can be employed.

Making the structural work in a frame residence tight, well braced, free from large unused open spaces, free from possibilities of large cracks opening, help to make it more soundproof. Most

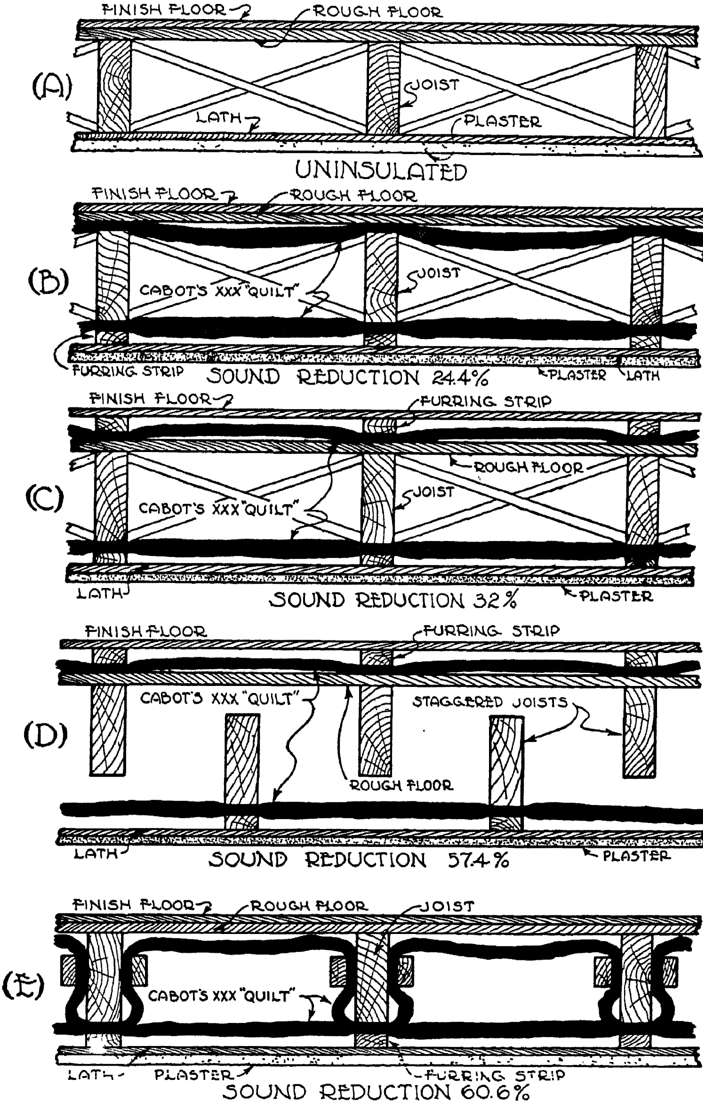


Fig. 73. Sections of Floor Showing Four Methods of Sound Reduction
Courtesy of Samuel Cabot, Incorporated, Boston, Massachusetts

forms of ordinary insulation can be used in roofs, sidewalls, etc., to prevent condensation, as explained in Chapter VII.

Vibration in a residence is not likely to occur from other sources than air conditioning or forced circulation ducts. Motors of any appreciable vibratory possibility besides heating and conditioning

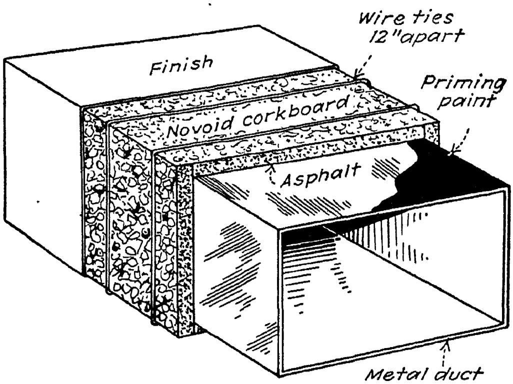


Fig. 74. Application of Thermal Insulation to Exterior of Duct

Courtesy of Cork Import Corporation, New York

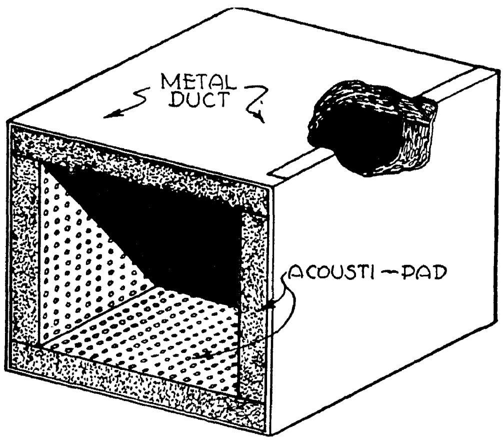


Fig. 75. Application of Vibration Insulation to Interior of Duct

Courtesy of Burgess Battery Company, Chicago, Illinois. Licensed under Patents of C. F. Burgess Laboratories, Inc.

motors, are not likely to be used and these motors are usually mounted on the basement concrete floor where vibration will not cause trouble. See explanations in Chapters II and VII.

Duct insulation is of two kinds; on the outside of the duct as protection against heat loss and on the inside as a protection against noise and vibration from heating or conditioning apparatus. On

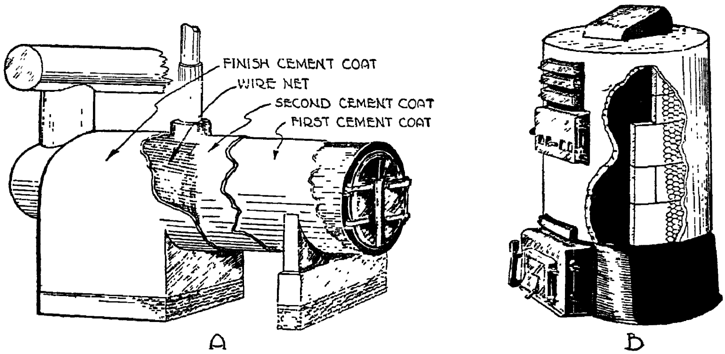


Fig. 76. Application of Insulation to Boilers

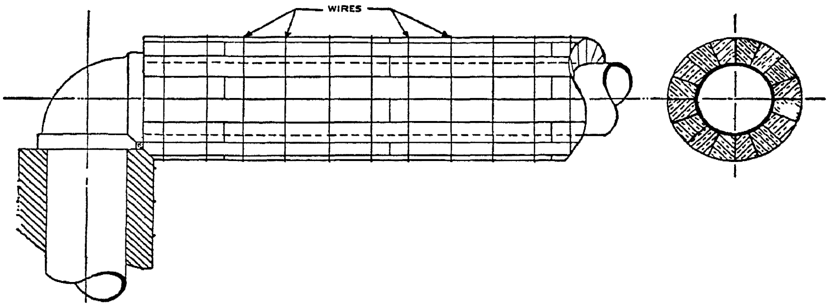


Fig. 77. Cork Insulation on Pipe
Courtesy of Armstrong Cork Products Company, Lancaster, Pennsylvania

the outside, various rigid forms of insulation can be used, Figs. 74 and 23, and on the inside, special types such as Burgess Acousti-Pad (see Chapters III and VII and Fig. 75, also specifications in Chapter VII). Not all types can be used in ducts because the surface must not offer resistance to air flow.

Where surface of the insulation will permit, rigid insulation is sometimes used to completely construct the duct, thus providing both types of insulation.

Where boilers are used for heating purposes, insulations such

as Ruberoid asbestos range jackets and asbestos cements and blocks are employed to insulate against heat loss and fire. Fig. 76A and B show where such types are used. Aluminum foil type can also be used if temperatures do not exceed 1250°F.

Steam, hot water, and similar pipes require insulation if they are to function without severe heat losses. Such insulations as

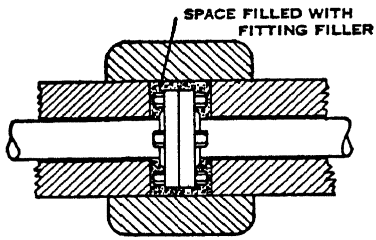


Fig. 78. Cork Insulation for Flange

Courtesy of Armstrong Cork Products Company, Lancaster, Pennsylvania

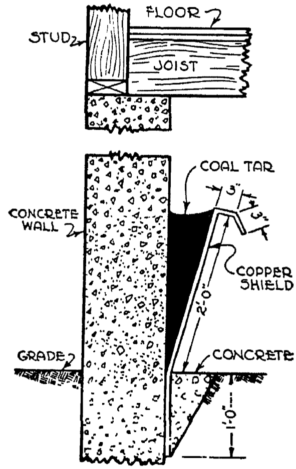


Fig. 79. Termite Shield for Existing Buildings

Courtesy of American Builder, Chicago, Illinois

Ruberoid, Armstrong cork, aluminum foil, etc., are used to encase the pipe lines and various couplings, flanges, etc.

Figs. 77 and 78 show typical examples of insulation used for pipes. Ice-water lines and other special piping are insulated in much the same manner. (See further explanation in Chapter VII.)

Fig. 79 shows a termite shield for unprotected existing buildings. A copper shield is rested against the wall, with the bottom edge in a shallow trench. The trench is then filled with concrete and allowed to harden. When the concrete is hard, the top of the shield is pulled away from the wall and the space between shield and wall is filled with coal-tar pitch.

Another method of termite insulation uses a continuous copper shield on top of the foundation wall, Fig. 80. Cone-shaped shields

of non-corrosive metal are securely soldered to all pipes that enter the house. These safeguards turn back attacks of termites.

Asbestos paper, plain and corrugated, is generally used to insulate round furnace pipes, leaders, etc. Rigid types of insulation can be used on rectangular-shaped pipes that require greater insulation. Magnesia blocks, etc., can be used for this purpose, too, as specified

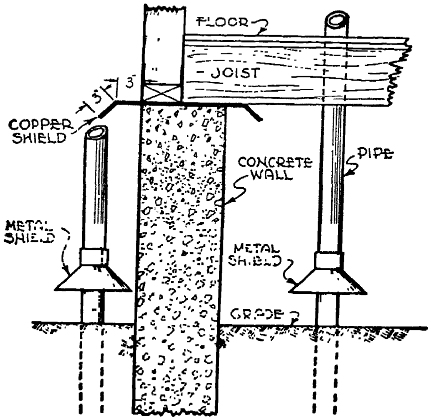


Fig. 80. Termite Protection in New Buildings

Courtesy of American Builder, Chicago, Illinois

in the Ruberoid specifications in Chapter VII. See also additional general data relative to furnace pipe insulation in Chapter VII.

Brick Veneer Residences. A brick veneer residence is here assumed as being exactly like a frame residence except that 4 inches of brick masonry replace siding.

Figs. 81 and 82B illustrate the use of rigid sheathing in a brick veneer wall. It will be noted that in both figures the heavy black lines indicate rigid type insulation used in place of sheathing and lath. Fig. 82B shows how the insulation is given a snug fit at plates, sills, etc. Either foil or loose wool could readily be used, as shown in Fig. 81. Blanket or quilt types could be employed exactly as shown by Figs. 54 and 55 and bat type as shown in Fig. 56. In the former case, the sill and plate treatment shown in Fig. 57 can be followed. Any combination of the various types of insulation can readily be used depending on costs, other individual conditions, and locality, as explained elsewhere.

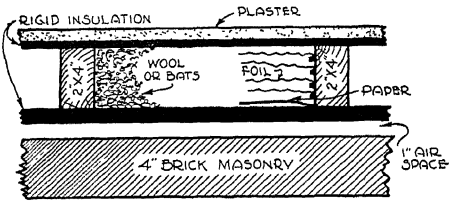


Fig. 81. Insulation in Brick Veneer Wall

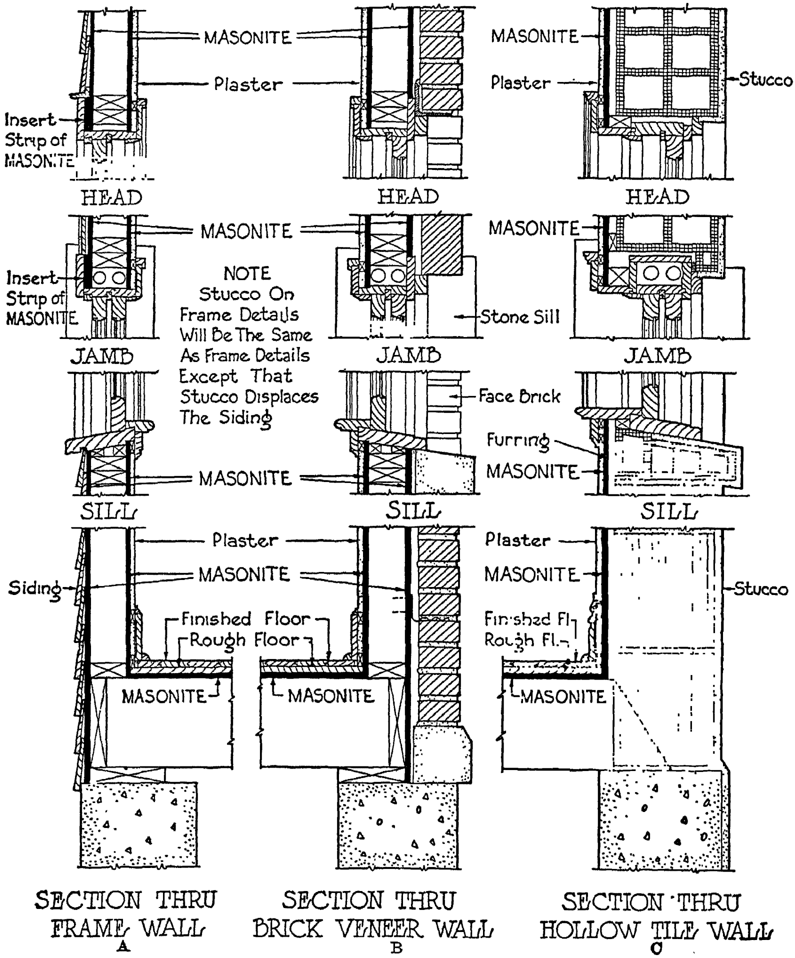


Fig. 82. Rigid Insulation in Various Wall Types
Courtesy of The Masonite Company, Chicago, Illinois

Partitions, roofs, basements, floors, etc., for a brick veneer house are insulated in the same manner as explained for frame houses. In fact, the only difference between frame and brick veneer house insulation concerns the outside surfacing, and coefficient differences are taken up in Chapter V under consideration of f_i and f_o.

The brick veneer house requires almost the same fireproofing as a frame house, the only differences being that the brick outside surfacing adds a measure of fire prevention not found in a frame house.

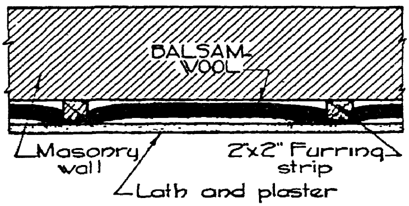


Fig. 83. Section of Masonry Wall Showing Blanket Insulation

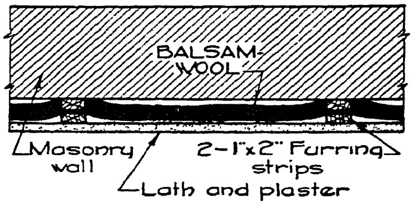


Fig. 84. Method of Applying Blanket Insulation to Brick Wall

Sound, vibration, condensation, boiler, pipe, termite, duct, and furnace pipe insulations for a brick veneer house are exactly as described for frame houses.

Residences Having Solid Brick Walls. Houses having solid brick walls on the outside and wood frame partitions on the inside are insulated in about the same manner as the frame house, the brick wall only requiring somewhat different treatment.

Figs. 83 and 84 show how blanket or quilt type insulation is used to insulate a brick wall. Rigid types may be used by first furring and applying insulation to the furring strips. This insulation can be used for plaster base as well. Foil can also be used. Partitions, floors, and roofs are insulated as explained for a frame house. Around windows, etc., the insulation is applied as shown by Fig. 82C.

Because of the solid masonry walls in this type of house, less consideration need be given to fireproofing. Otherwise the insulation procedure is the same as for a frame house.

Sound, vibration, boiler, pipe, termite, duct, and furnace piping insulation is similar to that in a frame house. Where a solid masonry wall is involved, more insulation against condensation is generally required. This is explained in Chapter VII.

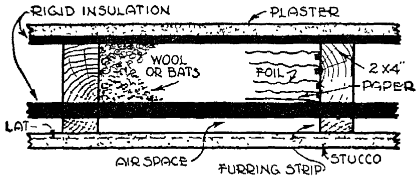


Fig. 85. Section of Stucco and Frame Wall Showing Application of Various Insulations

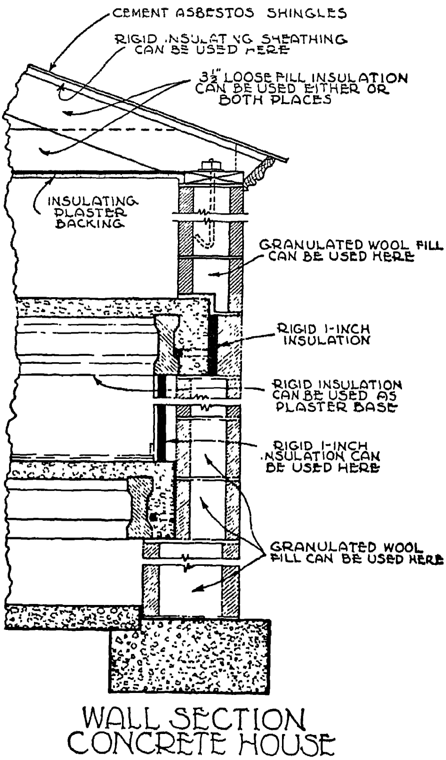


Fig. 86. Section of Concrete Block Wall Showing Application of Insulation

Courtesy of Portland Cement Association, Chicago, Illinois

Residences of Stucco on Tile. Insulation is applied to houses having tile and stucco, or brick and tile, in much the same manner as to brick houses. All other requirements are like those for frame

house insulation. Fig. 82C is a typical example of insulation applied to a tile and stucco or brick and tile wall.

Residences of Stucco on Frame. A frame wall with stucco exterior is insulated as shown in Fig. 85. Rigid insulation may form sheathing and plaster bases; blanket or quilt types can be used as shown in Fig. 54, or bats as shown in Fig. 56. Wool or foil, or any combination of all these insulations can be employed.

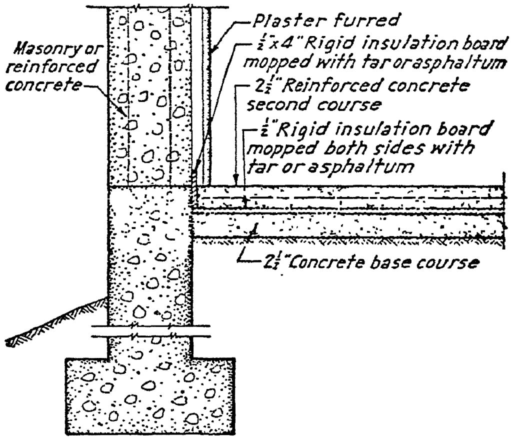


Fig. 87. Section Showing Insulated and Waterproofed Concrete Floor

Courtesy of Portland Cement Association, Chicago, Illinois

The house having a frame-stucco wall will be insulated in all respects as is a frame house.

Concrete Houses. Figs. 86, 87, and 88 show typical side-wall and floor constructions for concrete houses of blocks and poured concrete. Fig. 86 is self-explanatory as to the use of insulation in amount and location to suit the designer. Fig. 87 shows how rigid insulation is used on the floors; Fig. 88, on side walls and ceilings.

Granular or wool type insulation can be used between the concrete joists if desired. In either poured concrete or concrete block construction, the interior partitions are generally of concrete and could be insulated with rigid insulation as plaster backing if required, although this is seldom done because, as shown in Table 22, Chapter V, such walls may be built of concrete having a good thermal resistance. Various types of interior finish such as Nu-wood could

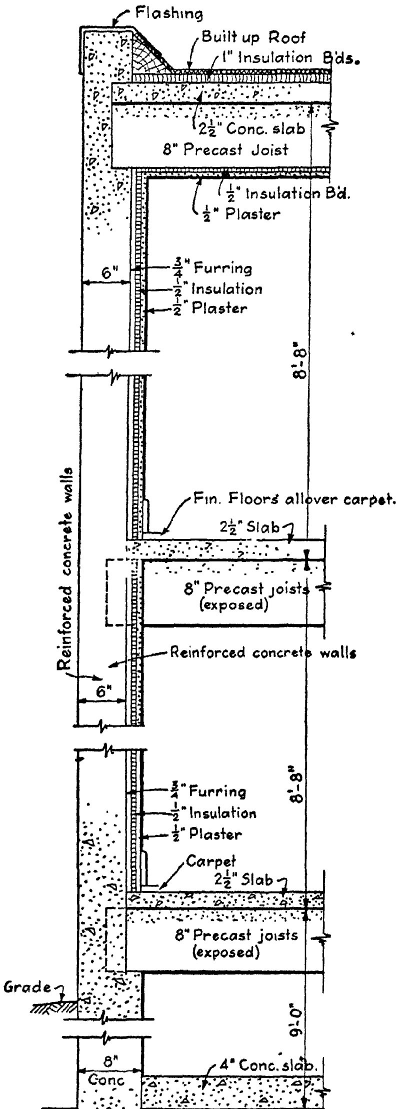


Fig. 88. Section of Wall in Concrete House Showing Typical Methods of Insulation

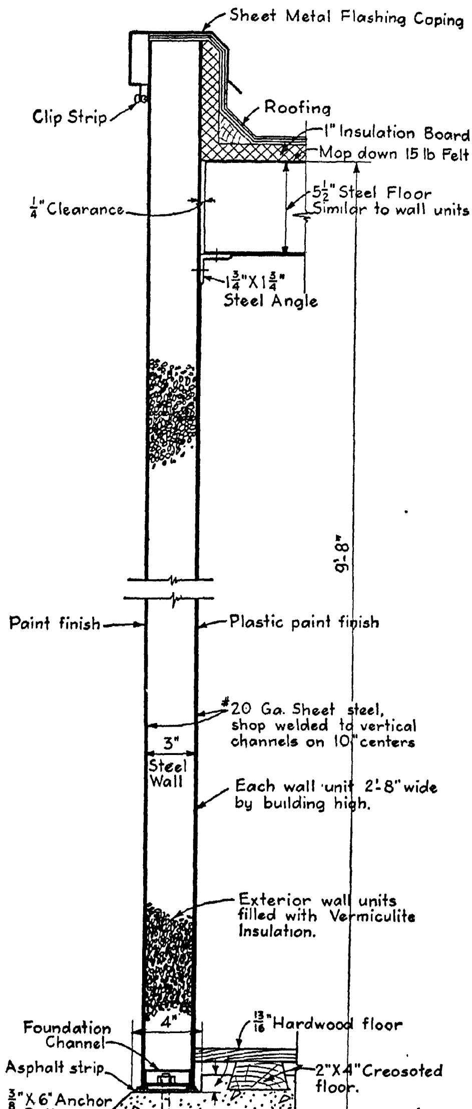


Fig. 89. Section of Wall in Steel House Showing Typical Methods of Insulation

Courtesy of American Builder, Chicago, Illinois

be used throughout the interior. If roofs and attic floors in either type construction are of wood, they could be insulated as indicated in Fig. 86. Condensation should be given careful consideration, and insulation planned if required. (See explanations in Chapters II and VII.)

As shown by Table 36 in Chapter VII, concrete, in itself, possesses good sound-reduction properties. Additional sound insulation can be had in the form of absorption by using a blanket form such as Cabot's Quilt or Balsam Wool, installing it in much the same manner as shown in Fig. 83.

Methods of insulation for vibration, piping, ducts, etc., are the same as those already explained. Insulation against termites is not required.

Steel Houses. Figs. 89 and 90 show typical details for insulating a steel house, and it will be noted that the loose-fill type of wool is used 100 per cent. The figures relating to the application of insulation are self-explaining. Wall finishes could easily be made from rigid types of insulation, such as Nu-wood, or rigid plaster backing could be applied and plastered in the usual manner.

Other conditions are either not considered, such as protection against fire and termites, or else are handled as has been already explained.

Vibration Insulation. Machine insulation against vibration is thoroughly explained in Chapter VII, but Fig. 91 shows how such insulation may be installed in typical cases. Motors, etc., are mounted on bases constructed of insulation. Lighter weight machinery is sometimes mounted on or suspended by springs which take up the vibration.

Radiators. Fig. 92 shows how the aluminum foil type of insulation is used to make common steam radiators more efficient.

Everyone, particularly architects, engineers, and owners of large buildings, fully realizes that the heat loss through walls behind radiators is tremendous. If one touches the wall behind an uninsulated radiator he finds it to be "sizzling hot."

It is a well-known fact that heat flows out through a wall at a rate in direct ratio to the difference between the temperature inside of a house and the temperature outside. For example: Assume that the temperature of the air in the space between an uninsulated radia-

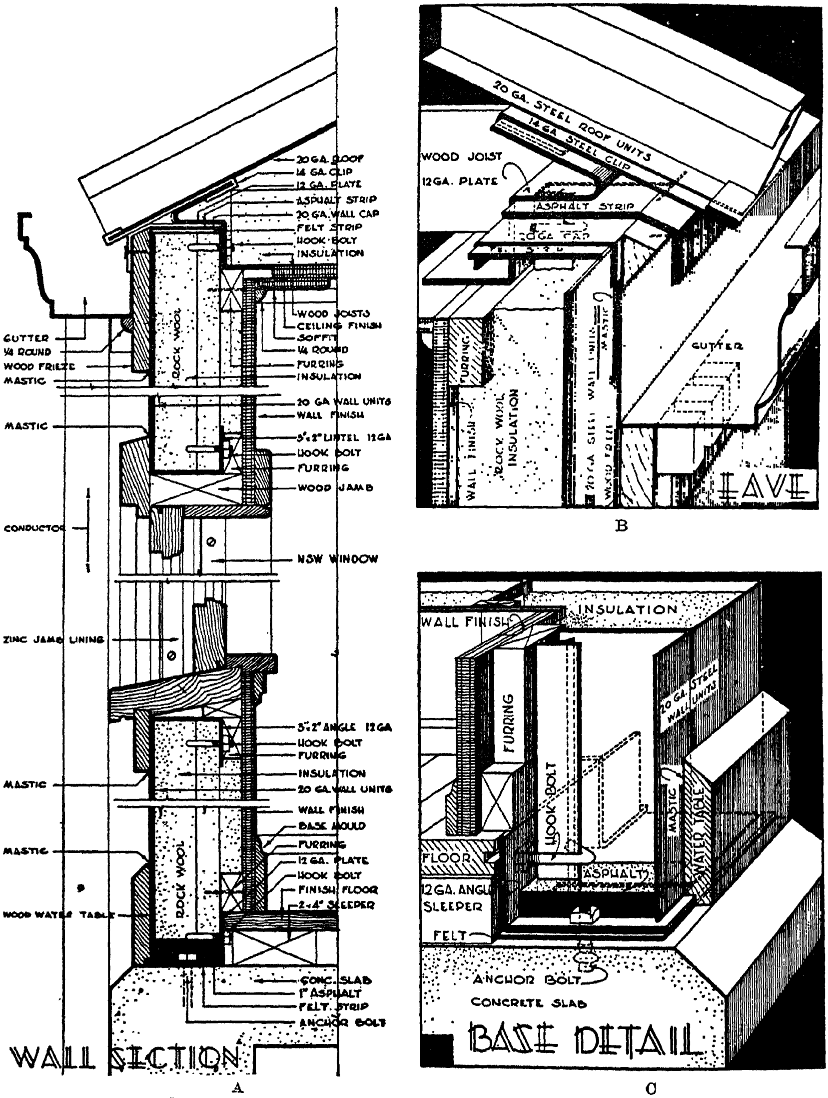


Fig. 90. Sections Showing Steel House Details and Typical Methods of Insulation
Courtesy of American Builder, Chicago, Illinois

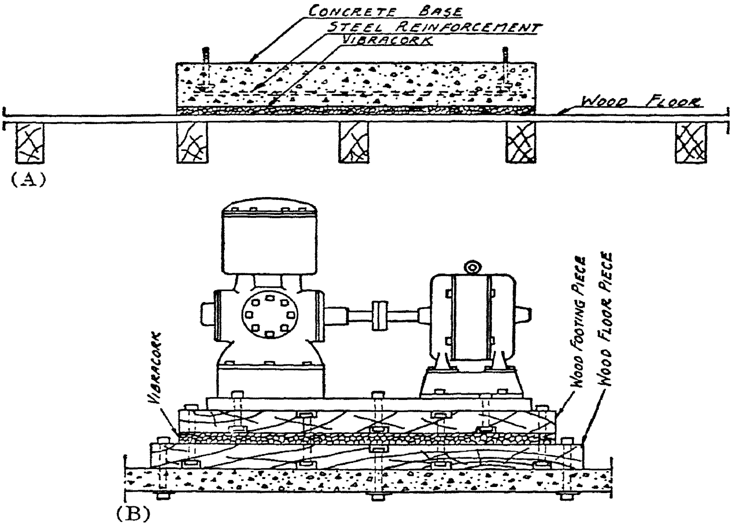


Fig. 91. Sections Showing Application of Vibration Insulation. (A) A Floating Foundation on Mill Type Floor; (B) Pump and Motor on Same Bed Plate

Courtesy of Armstrong Cork Products Company, Lancaster, Pennsylvania

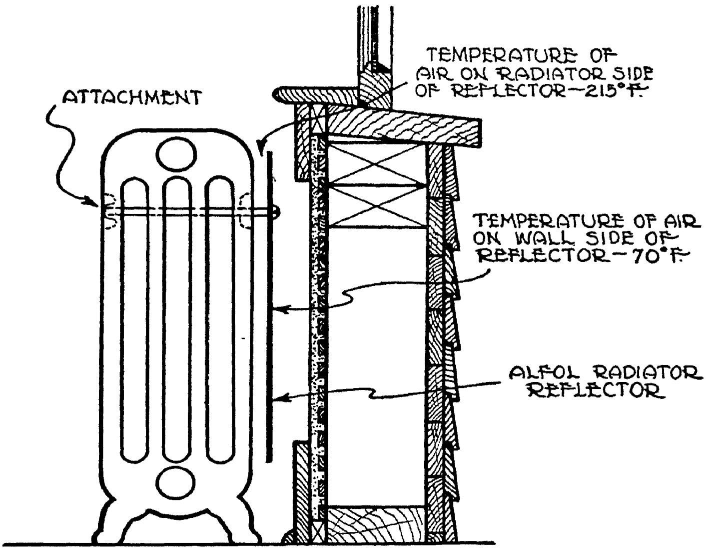


Fig. 92. Insulation Used as a Heat Reflector

Courtesy of Alfol Company, New York

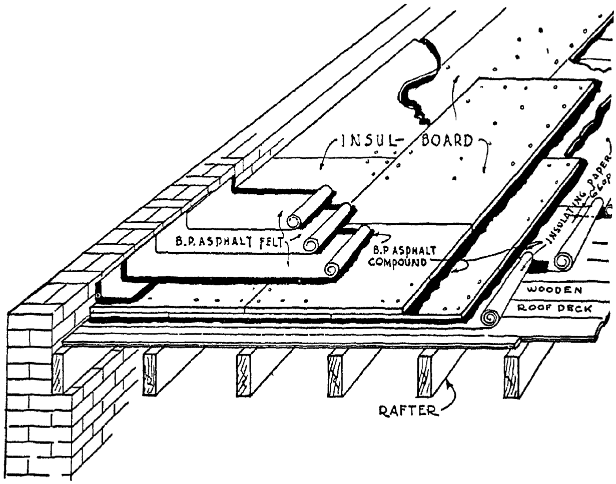


Fig. 93. Section of Wooden Roof Showing Application of Rigid Insulation

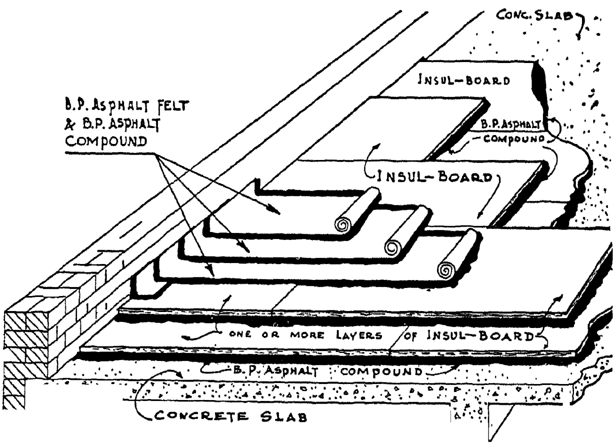


Fig. 94. Section of Concrete Roof Showing Application of Rigid Insulation

tor and the wall of the house is 215°F, and that the atmospheric temperature outdoors is 20°F. Then the temperature difference is 195°F.

Now, by placing an Alfol heat reflector on the radiator, the temperature of the air in the space between the reflector and the

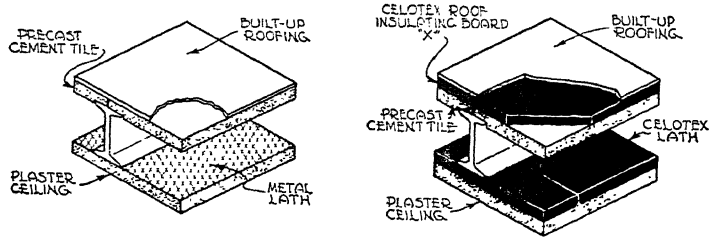


Fig. 95. Typical Roof Insulation on Precast Cement Tile Construction

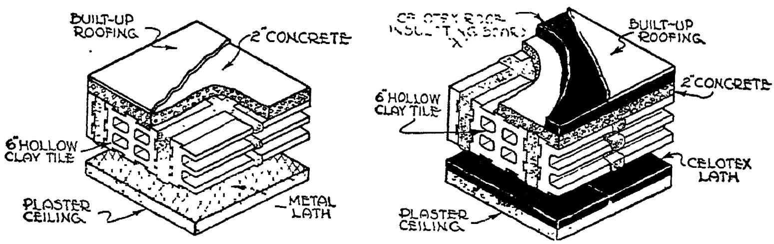


Fig. 96. Typical Roof Insulation on Hollow Clay Tile Construction

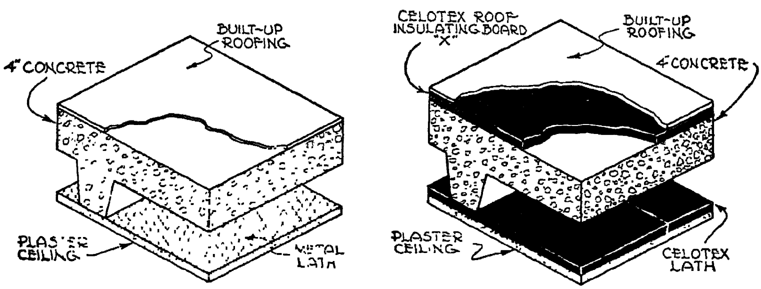


Fig. 97. Typical Roof Insulation on Concrete Slab Construction

wall is reduced to 70°F. The atmospheric temperature outdoors being 20°F, the temperature difference is 50°F.

Obviously the amount of heat that flowed through the wall from the uninsulated radiator has been reduced about 75 per cent by the use of the Alfol heat reflector.

Flat Roofs. This type of roof is generally found on apartment

$$U=\frac{1}{\frac{1}{f_i}+\frac{x_1}{k_1}+\frac{x_2}{k_2}+\frac{1}{f_i}+\frac{1}{f_i}+\frac{x_3}{k_3}+\frac{x_4}{k_4}+\frac{1}{f_o}}$$

or, simplified,

$$U=\frac{1}{\frac{3}{f_i}+\frac{x_1}{k_1}+\frac{x_2}{k_2}+\frac{x_3}{k_3}+\frac{x_4}{k_4}+\frac{1}{f_o}} \tag{7}$$

It should be remembered that where an air space is 1.5 inches or less, $\frac{1}{a}$ is used in the formula, as explained for formulas (4) and (5) and that where the air space is more than 1.5 inches the $\frac{1}{f_i}$ unit should be used as in formulas (6) and (7).

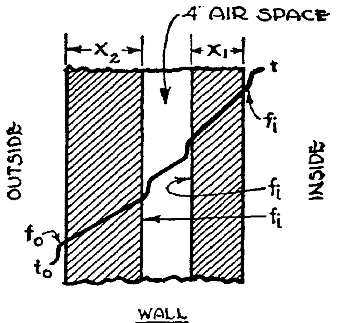


Fig. 102. A Wall with Wide Air Space

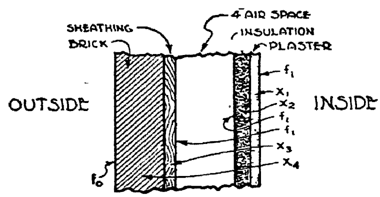


Fig. 103. A Typical Wall

Sufficient explanation has now been given on the formulas and their application. The reader should take special care to thoroughly understand all the foregoing material before going further.

Summary of Surface and Air Space Conductance Values. The principles explained for Fig. 101 and Table 1 relative to ascertaining values for inside surface conductance (f_i), outside surface conductance (f_o), and air spaces (a), were given in full detail in order that the *exact* methods may be known and fully understood.

Such values as shown in Fig. 101 and Table 1 are the results of laboratory tests rather than mathematical processes because the process of heat transfer across an air space is too complex to be calculated practically by mathematics. For this reason only the laboratory results are given here.

In the practical application of f_i, f_o, and a values in formulas for calculating U, there is an easier and quicker method commonly used by all heating and ventilating engineers. It gives results almost as accurate as the method explained for Fig. 101 and Table 1. This practical method consists of using set values for f_i, f_o, and a, in place of the varying values found in Fig. 101 and Table 1, and assumes wind velocities of 15 miles per hour in all cases unless otherwise specified. In rare cases where another velocity is specified, values from Fig. 101 or Table 1 can be used as required.

In Table 2, page 112, will be found a section giving conductivity (k) and conductance (C) values for f_i, f_o, and a. *These values are used in solving formulas for U in all the examples and problems to follow, unless otherwise specified.*

In formula (7) instead of using two values of f_i for the air space, the single value taken from Table 2 will be used. Thus a is substituted for f_i so far as the air space is concerned. Where more than one air space is encountered, the air space value a taken from Table 2 is used for each air space in place of the f_i values.

Therefore, for a wall such as Fig. 103, the formula becomes

$$U = \frac{1}{\frac{1}{f_i}+\frac{x_2}{k_2}+\frac{1}{a}+\frac{x_3}{k_3}+\frac{x_4}{k_4}+\frac{1}{f_o}}$$

This is solved in the same manner as already explained taking f_i, f_o and a values from Table 2, namely, f_i is 1.65, f_o is 6.00, and a is 1.10.

To sum up the above practical method of using surface conductances and air space values the following statement can be used.

Always assume inside and outside surfaces and the air space or spaces, as the case may be, to have values of 1.65, 6.00, and 1.10 respectively as shown in Table 2.

Note. All U values in Tables 3 to 13 were calculated following the above statement.

Explanation of Tables. *Table 1.* With the exception of the term, mean temperature, this table has already been explained. Mean temperature simply means the average between inside and outside temperatures. If the inside temperature is 70°F. and the outside temperature is 10°F., the mean temperature is 40°F. In

order to use this table we must always calculate mean temperature. Thus, if the mean temperature is 40°F. and the air space is ¼ inch wide (.250), the coefficient, or value of a, is 1.480.

Table 2. This table shows conductivities (k) and conductances (C) of common building materials and for some insulation. It will be noted that all conditions for each material are shown, that is, all common conditions. For example, the table begins with brick. Common and face brick are given and the values of k shown. Another item shown is tile, and the various thicknesses are all stated separately. In like manner all other common materials and some insulation are shown and the proper values of k or C given. The reader will note one column headed, "Conductivity (k) or Conductance (C)." It has already been explained that for some materials, such as tile, the value of C is given. The value shown in this column for any material can be used freely, because either way it is correct. The column headed, "Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)" gives the same values as the k and C column expressed slightly differently. For example, take common brick. Its conductivity is 5.00. In other words, the value of k is 5.00. Now, the Resistance column says $\frac{1}{k}$ or R. From page 97 we can readily see that $\frac{1}{k}=R$. We can prove this by substituting 5.00 for k. Hence we have $\frac{1}{5.00}$ and this equals .20. This will be shown in more detail later on in this chapter. For the present it is enough to know how to find k or C in Table 2.

Table 3. In this table there are several examples of typical construction in masonry walls of various thicknesses. It will be noted that the value of U is given in all cases; therefore when we are considering a wall of this kind, having interior finish and insulation as shown, we need not go to the trouble of calculating the value of U. We can simply select it from the table and use formula (1) to find total heat loss. However, if we had in mind a wall of a design somewhat different from any shown in the table, then we would have to use one of the formulas (2) to (7), as the case might be, to determine the value of U before we could use formula (1).

As an example of the use of Table 3, suppose we were considering a solid concrete wall 10 inches thick, which had plaster on wood lath, furred on the inside. To ascertain the value of U we would find the term *concrete* in the table on the left-hand side. On the right-hand side of the table we would look for plaster on wood lath—furred. This is found in column C. In this column, just opposite the line marking 10-inch concrete we would find the U value, 0.34.

Table 4. This table deals with masonry walls having various types of veneers, and is used in much the same way as Table 3. If we are considering a wall that coincides with one specified in the table, it is a simple matter to select the proper over-all coefficient. Odd types of walls will require the use of such formulas as (2) to (7).

Table 5. Residences are largely of so-called frame (wood) construction. Some of the most common types are illustrated at the left-hand side of this table. At the right-hand side of the table, columns A through J list different plaster specifications and insulation. It will be noted that exterior finish and sheathing are also considered. As an example of the use of this table, we will assume that a wall is composed of 2×4 studs, 1-inch wood sheathing, wood siding, and plaster on wood lath applied to studding. This is the first sketch at top of the left-hand page in Table 5. It is wall number 41. Now finding the proper column for wood lath and plaster, A, on the right-hand side of the table and noting the coefficient opposite wall 41, we see that this coefficient is 0.25. A wall assembly of any other type than those specified in the table would require the use of such formulas as (6) or (7) in order to determine the value of U.

Tables 6 and 7. These two tables apply to interior partitions and the manner of finding the over-all coefficient is obvious.

Table 8. This table lists over-all coefficients for combination floor and ceiling, such as the floor of the second story of a residence, and the ceiling of the first story or floor; or attic floors and second-story ceilings, etc. To use the table, determine the type of ceiling, insulation, if any, between joists, type of flooring, etc. Take as an example a ceiling of wood lath and plaster applied directly to joists, no insulation between joists, and oak flooring on yellow pine subflooring on joists. Wood lath and plaster ceiling is third from the top at the left-hand side of the table. Follow this line to the right

until it reaches column D where the specified flooring is found. The coefficient is .24.

Note: In studying these tables the reader can obtain a preliminary idea relative to the value of insulation. The smaller the coefficient the more effective is the insulation. Thus a coefficient of .13 is better than .46. However, other considerations, such as fireproofing, sound proofing, etc., sometimes prevent any comparisons. When these comparisons are used, they must be considered with thermal insulation.

Tables 9, 10, 11, and 12. From explanations of previous tables these tables should be easily understood. It must be kept in mind that these tables do not illustrate all possible constructions but only those in most common use, and that any different construction or different means of insulating will require the use of such formulas as (2) to (7) before formula (1) can be employed. Table headings should be studied in all cases.

Table 13A. Besides calculating heat losses through walls, roofs, and partitions, it is necessary to take into account windows and doors. Table 13 lists coefficients (U) for various types of windows. In determining heat loss through a double hung window, for example, we would use 1.13 as the value of U in formula (1). This value would be multiplied by the area of the window and the product by the temperature difference.

Table 13B. This table gives U values for the most frequently used door thicknesses. These coefficients are used as explained in the case of windows. All window and door areas are figured separately from all areas.

Note: The reference books mentioned on the various tables need not be obtained in order to use the tables. Such references merely name the source of information and more detailed data.

Tables 14, 15 and 16. These tables give coefficients for typical insulations by their trade names. In most cases, Table 2 gives such coefficients also, but not by name. When (R) values are required instead of conductivity (k), use the method given in the explanation of Table 2, page 109.

Table 17. It will be noted from a study of Table 14 that most types of insulation have approximately the same coefficients. Table 17 has been prepared with this in mind. It shows fuel savings with various thicknesses and types of insulation.

TABLE 1. CONDUCTANCES OF AIR SPACES[a] AT VARIOUS MEAN TEMPERATURES

Mean Temp Deg Fahr	Conductances of Air Spaces for Various Widths in Inches						
	0.128	0.250	0.364	0.493	0.713	1.00	1.500
20	2.300	1.370	1.180	1.100	1.040	1.030	1.022
30	2.385	1.425	1.234	1.148	1.080	1.070	1.065
40	2.470	1.480	1.288	1.193	1.125	1.112	1.105
50	2.560	1.535	1.340	1.242	1.168	1.152	1.149
60	2.650	1.590	1.390	1.295	1.210	1.195	1.188
70	2.730	1.648	1.440	1.340	1.250	1.240	1.228
80	2.819	1.702	1.492	1.390	1.295	1.280	1.270
90	2.908	1.757	1.547	1.433	1.340	1.320	1.310
100	2.990	1.813	1.600	1.486	1.380	1.362	1.350
110	3.078	1.870	1.650	1.534	1.425	1.402	1.392
120	3.167	1.928	1.700	1.580	1.467	1.445	1.435
130	3.250	1.980	1.750	1.630	1.510	1.485	1.475
140	3.340	2.035	1.800	1.680	1.550	1.530	1.519
150	3.425	2.090	1.852	1.728	1.592	1.569	1.559

[a]Thermal Resistance of Air Spaces by F. B. Rowley and A. B. Algren (A.S.H.V.E. TRANSACTIONS, Vol. 35, 1929).

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATORS[a]

The coefficients are expressed in Btu per hour per square foot per degree Fahrenheit per 1 in. thickness, unless otherwise indicated.

Material	Description	Density (Lb per Cu Ft)	Mean Temp. (Deg Fahr)	Conductivity (k) or Conductance (C)	Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)	Authority
MASONRY MATERIALS						
Brick	Common	—	—	5.00*	0.20	—
	Face	—	—	9.20*	0.11	—
Brickwork	Damp or wet	—	—	5.00[b]	0.20	(2)
Cement Mortar	Typical	—	—	12.00*	0.08	—
Cinder Concrete	Typical	110.0	75	5.20*	0.19	(3)
Cinder Blocks[c]	Typical (8 in.)	—	—	0.62†*	1.61	—
	" (12 in.)	—	—	0.51†*	1.96	—
Concrete	Typical	—	—	12.00*	0.08	—
	1-2-4 mix	143.0	69	9.46	0.11	(4)
	Various ages and mixes[d]	—	—	11.35 *to* 16.36	—	(5)
	Cellular	40.0	75	1.06	0.94	(3)
	"	50.0	75	1.44	0.69	(3)
	"	60.0	75	1.80	0.56	(3)
	"	70.0	75	2.18	0.46	(3)
	Typical gypsum fiber concrete, 87.5% gypsum and 12.5% wood chips	51.2	74	1.66*	0.60	(4)
	Special concrete made with an aggregate of hardened clay—1-2-3 mix	101.0	70	3.98	0.25	(3)
Concrete Blocks[c]	Typical (8 in.)	—	—	1.00†*	1.00	—
	" (12 in.)	—	—	0.80†*	1.25	—
	Special concrete block made with an aggregate of hardened clay—4 x 8 x 16 in., 3 cores, 18% voids	74.0	—	0.66†	1.51	(3)
	Special concrete block made with an aggregate of hardened clay—8 x 8 x 16 in., 4 cores, 35% voids	74.5	—	0.30†	3.33	(3)
Stone	Typical	—	—	12.50*	0.08	—
Stucco	"	—	—	12.00*	0.08	—
Tile	Typical hollow clay (4 in.)	—	—	1.00†*	1.00	—
	" " " (6 in.)[e]	—	—	0.64†*	1.57	—
	" " " (8 in.)[e]	—	—	0.60†*	1.67	—
	" " " (10 in.)[e]	—	—	0.58†*	1.72	—
	" " " (12 in.)[e]	—	—	0.40†*	2.50	—
	" " " (16 in.)[e]	—	—	0.31†*	3.23	—
	Hollow clay (2 in.) ½-in. plaster both sides	120.0	110	1.00†	1.00	(2)
	Hollow clay (4 in.) ½-in. plaster both sides	127.0	100	0.60†	1.67	(2)
	Hollow clay (6 in.) ½-in. plaster both sides	124.3	105	0.47†	2.13	(2)
	Hollow gypsum (4 in.)	—	—	0.46†*	2.18	—
	Solid gypsum	51.8	70	1.66	0.60	(4)
	Solid gypsum	75.6	76	2.96	0.34	(4)
Tile or Terrazzo	Typical flooring	—	—	12.00*	0.08	—

AUTHORITIES:

[1]U. S. Bureau of Standards, tests based on samples submitted by manufacturers.
[2]A. C. Willard, L. C. Lichty, and L. A. Harding, tests conducted at the University of Illinois.
[3]J. C. Peebles, tests conducted at Armour Institute of Technology, based on samples submitted by manufacturers.
[4]F. B. Rowley, tests conducted at the University of Minnesota.
[5]A.S.H.V.E. Research Laboratory.
[6]E. A. Allcut, tests conducted at the University of Toronto.
[7]Lees and Chorlton.

*Recommended conductivities and conductances for computing heat transmission coefficients.

†For thickness stated or used on construction, not per 1-in. thickness.

[a]For additional conductivity data see Table 14, Page 63, *1934 A.S.R.E. Data Book.*

[b]Recommended value. See *Heating, Ventilating and Air Conditioning*, by Harding and Willard, revised edition, 1932.

[c]One air cell in the direction of heat flow.

[d]See A.S.H.V.E. Research Paper, *Conductivity of Concrete*, by F. C. Houghten and Carl Gutberlet (A.S.H.V.E. TRANSACTIONS, Vol. 37, 1931).

[e]The 6-in., 8-in., and 10-in. hollow tile figures are based on two cells in the direction of heat flow. The 12-in. hollow tile is based on three cells in the direction of heat flow. The 16-in. hollow tile consists of one 10-in. and one 6-in. tile, each having two cells in the direction of heat flow.

[f]Not compressed.

[g]Roofing, 0.15-in. thick (1.34 lb per sq ft), covered with gravel (0.83 lb per sq ft), combined thickness assumed 0.25.

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATORS—Continued

The coefficients are expressed in Btu per hour per square foot per degree Fahrenheit per 1 in. thickness, unless otherwise indicated.

Material	Description	Density (Lb per Cu Ft)	Mean Temp. (Deg Fahr)	Conductivity (k) or Conductance (C)	Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)	Authority
INSULATION—BLANKET OR FLEXIBLE TYPES						
Fiber	Typical	....	....	0.27*	3.70	—
	Chemically treated wood fibers held between layers of strong paper[f]	3.62	70	0.25	4.00	(3)
	Eel grass between strong paper[f]	4.60	90	0.26	3.85	(1)
	" " " " "	3.40	90	0.25	4.00	(1)
	Fabric with non-metallic reflective surface (1/32 in. thick)	....	70	0.33†	3.03	(3)
	Flax fibers between strong paper[f]	4.90	90	0.28	3.57	(1)
	Chemically treated hog hair between kraft paper[f]	5.76	71	0.26	3.85	(3)
	Chemically treated hog hair between kraft paper and asbestos paper[f]	7.70	71	0.28	3.57	(3)
	Hair felt between layers of paper[f]	11.00	75	0.25	4.00	(3)
	Kapok between burlap or paper[f]	1.00	90	0.24	4.17	(1)
	Jute fiber[f]	6.70	75	0.25	4.00	(3)
INSULATION—SEMI-RIGID TYPE						
Fiber	Felted cattle hair[f]	13.00	90	0.26	3.84	(1)
	" " "	11.00	90	0.26	3.84	(1)
	Flax[f]	12.10	70	0.30	3.33	(3)
	Flax and rye[f]	13.60	90	0.32	3.12	(1)
	Felted hair and asbestos[f]	7.80	90	0.28	3.57	(1)
	75% hair and 25% jute[f]	6.30	90	0.27	3.70	(1)
	50% hair and 50% jute[f]	6.10	90	0.26	3.85	(1)
	Jute[f]	6.70	75	0.25	4.00	(3)
	Felted jute and asbestos[f]	10.00	90	0.37	2.70	(1)
	Compressed peat moss	11.00	70	0.26	3.84	(3)
INSULATION—LOOSE FILL OR BAT TYPE						
Fiber	Made from ceiba fibers[f]	1.90	75	0.23	4.35	(3)
	" " " "	1.60	75	0.24	4.17	(3)
	Fibrous material made from dolomite and silica	1.50	75	0.27	3.70	(3)
	Fibrous material made from slag	9.40	103	0.27	3.70	(1)
Glass Wool	Fibrous material 25 to 30 microns in diameter, made from virgin bottle glass	1.50	75	0.27	3.70	(3)
Granular	Made from combined silicate of lime and alumina	4.20	72	0.24	4.17	(3)
	Made from expanded aluminum-magnesium silicate	6.20	42	0.32	3.12	(3)
Gypsum	Cellular, dry	30.00	90	1.00	1.00	(1)
	" "	24.00	90	0.77	1.30	(1)
	" "	18.00	90	0.59	1.69	(1)
	" "	12.00	90	0.44	2.27	(1)
	Flaked, dry and fluffy[f]	34.00	90	0.60	1.67	(1)
	" " " "	26.00	90	0.52	1.92	(1)
	" " " "	24.00	75	0.48*	2.08	(3)
	" " " "	19.80	90	0.35	2.86	(1)
	" " " "	18.00	75	0.34	2.94	(3)
Mineral Wool	All forms, typical	....	....	0.27*	3.70	....
Regranulated Cork	About 3/16-in. particles	8.10	90	0.31	3.22	(1)
Rock Wool	Fibrous material made from rock	21.00	90	0.30	3.33	(1)
	" " " " "	18.00	90	0.29	3.45	(1)
	" " " " "	14.00	90	0.28	3.57	(1)
	" " " " "	10.00	90	0.27*	3.70	(1)
	Rock wool with a binding agent	14.50	77	0.33	3.03	(1)
	Rock wool with flax, straw pulp, and binder	14.50	75	0.38	2.63	(3)
	Rock wool with vegetable fibers	11.50	72	0.31	3.22	(3)
Sawdust	Various	12.00	90	0.41	2.44	(1)
Shavings	Various from planer	8.80	90	0.41	2.44	(1)
	From maple, beech and birch (coarse)	13.20	90	0.36	2.78	(1)
	Redwood bark	3.00	90	0.31	3.22	(1)
INSULATION—RIGID						
Corkboard	Typical	....	....	0.30*	3.33	—

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATORS—Continued

The coefficients are expressed in Btu per hour per square foot per degree Fahrenheit per 1 in. thickness, unless otherwise indicated.

Material	Description	Density (Lb per Cu Ft)	Mean Temp. (Deg Fahr)	Conductivity (k) or Conductance (C)	Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)	Authority
INSULATION—RIGID —Continued						
Corkboard	No added binder	14.00	90	0.34	2.94	(1)
	" " "	10.60	90	0.30	3.33	(1)
	" " "	7.00	90	0.27	3.70	(1)
	" " "	5.40	90	0.25	4.00	(1)
	Asphaltic binder	14.50	90	0.32	3.12	(1)
Fiber	Typical	—	—	0.33	3.03	—
	Core of fiber board coated two sides with non-metallic reflective surface (3/8 in. thick)	23.4	70	0.27†	3.70	(3)
	Fiber board coated one side with non-metallic reflective surface (3/16 in. thick)	—	75	0.49†	2.04	(3)
	Made from chemically treated wood fiber	20.00	70	0.36	2.78	(3)
	Made from chemically treated wood and vegetable fibers	25.00	75	0.38	2.63	(3)
	Chemically treated hog hair covered with film of asphalt	10.00	75	0.28	3.57	(3)
	Made from corn stalks	15.00	71	0.33	3.03	(3)
	" " exploded wood fiber	17.90	78	0.32	3.12	(4)
	" " hard wood fibers	15.20	70	0.32	3.12	(3)
	Insulating plaster 9/10-in. thick applied to 3/8-in. plaster board base	54.00	75	1.07†	0.93	(3)
	Made from licorice roots	16.10	81	0.34	2.94	(3)
	Made from 85% magnesia and 15% asbestos	19.30	86	0.51	1.96	(1)
	Made from shredded wood and cement	24.20	72	0.46	2.17	(3)
	" " sugar cane fiber	13.50	70	0.33	3.03	(3)
	Sugar cane fiber insulation blocks encased in asphalt membrane	13.80	70	0.30	3.33	(3)
	Made from wheat straw	17.00	68	0.33	3.03	(3)
	" " wood fiber	15.90	72	0.33	3.03	(3)
	" " " "	15.00	70	0.33	3.03	(3)
	" " " "	—	52	0.33	3.03	(6)
	" " " "	8.50	72	0.29	3.45	(3)
	" " " "	15.20	—	0.33	3.03	(3)
	" " " "	16.90	90	0.34	2.94	(1)
BUILDING BOARDS						
Asbestos	Compressed cement and asbestos sheets	123.00	86	2.70	0.37	(1)
	Corrugated asbestos board	20.40	110	0.48	2.08	(2)
	Pressed asbestos mill board	60.50	86	0.84	1.19	(1)
	Sheet asbestos	48.30	110	0.29	3.45	(2)
Gypsum	Gypsum between layers of heavy paper	62.80	70	1.41	0.71	(3)
	Rigid, gypsum between layers of heavy paper (1/2-in. thick)	53.50	90	2.60†	0.38	(1)
	Gypsum mixed with sawdust between layers of heavy paper (0.39-in. thick)	60.70	90	3.60†	0.28	(1)
Plaster Board	(3/8 in.)	—	—	3.73†*	0.27	—
	(1/2 in.)	—	—	2.82†*	0.35	—
ROOFING CONSTRUCTION						
Roofing	Asphalt, composition or prepared	70.00	75	6.50†*	0.15	(3)
	Built up—3/8-in. thick	—	—	3.53†*	0.28	—
	Built up, bitumen and felt, gravel or slag surfaced[a]	—	—	1.33†	0.75	(2)
	Plaster board, gypsum fiber concrete and 3-ply roof covering	52.40	76	0.58†	1.72	(4)
Shingles	Asbestos	65.00	75	6.00†*	0.17	(3)
	Asphalt	70.00	75	6.50†*	0.15	(3)
	Slate	201.00	—	10.37*	0.10	(7)
	Wood	—	—	1.28†*	0.78	—
PLASTERING MATERIALS						
Plaster	Cement	—	—	8.00	0.13	(2)
	Gypsum, typical	—	—	3.30*	0.30	—
	Thickness 3/8 in.	—	73	8.80†	0.11	(4)
Metal Lath and Plaster	Total thickness 3/4 in.	—	—	4.40†*	0.23	—
Wood Lath and Plaster	3/8-in. plaster, total thickness 3/4 in.	—	70	2.50†*	0.40	(4)

TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATORS—Continued

The coefficients are expressed in Btu per hour per square foot per degree Fahrenheit per 1 in. thickness, unless otherwise indicated.

Material	Description	Density (Lb per Cu Ft)	Mean Temp. (Deg Fahr)	Conductivity (k) or Conductance (C)	Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)	Authority
BUILDING CONSTRUCTIONS						
Frame	1-in. fir sheathing and building paper	....	30	0.71†*	1.41	(4)
	1-in. fir sheathing, building paper, and yellow pine lap siding	....	20	0.50†*	2.00	(4)
	1-in. fir sheathing, building paper and stucco	....	20	0.82†*	1.22	(4)
	Pine lap siding and building paper—siding 4 in. wide	....	16	0.85†*	1.18	(4)
	Yellow pine lap siding	....	....	1.28†*	0.78	....
Flooring	Maple—across grain	40.00	75	1.20	0.83	(3)
	Battleship linoleum (¼-in.)	....	....	1.36†*	0.74	....
AIR SPACE AND SURFACE COEFFICIENTS						
Air Spaces	Over ¾-in. faced with ordinary building materials	....	40	1.10†*	0.91	(4)
Surfaces, Ordinary	Still air (f_i)	....	....	1.65†*	0.61	(4)
	15 mph—(f_o)	....	....	6.00†*	0.17	(4)
Surface, Bright Aluminum	Still air (f_i)	....	60	1.18†	0.85	....
AIR SPACES FACED WITH BRIGHT ALUMINUM FOIL						
	Air space, faced one side with bright aluminum foil, over ¾-in. wide	....	50	0.46†*	2.17	(4)
	Air space, faced one side with bright aluminum foil, ⅜-in. wide	....	50	0.62†	1.61	(4)
	Air space, faced both sides with bright aluminum foil, over ¾-in. wide	....	50	0.41†*	2.44	(4)
	Air space, faced both sides with bright aluminum foil, ⅜-in. wide	....	50	0.57†	1.75	(4)
	Air space divided in two with single curtain of bright aluminum foil (both sides bright)					
	Each space over ¾-in. wide	....	50	0.23†*	4.35	(4)
	Each space ⅜-in. wide	....	50	0.31†	3.23	(4)
	Air space with multiple curtains of bright aluminum foil, bright on both sides, curtains more than ¾-in. apart, in standard construction:					
	2 curtains, forming 3 spaces	....	50	0.15†*	6.78	(4)
	3 curtains, forming 4 spaces	....	50	0.11†*	9.22	(4)
	4 curtains, forming 5 spaces	....	50	0.09†*	11.66	(4)
WOODS (Across Grain)						
Balsa		20.0	90	0.58	1.72	(1)
		8.8	90	0.38	2.63	(1)
		7.3	90	0.33	3.03	(1)
California Redwood	0% moisture	22.0	75	0.66	1.53	(4)
	0% "	28.0	75	0.70	1.43	(4)
	8% "	22.0	75	0.70	1.43	(4)
	8% "	28.0	75	0.75	1.33	(4)
	16% "	22.0	75	0.74	1.35	(4)
	16% "	28.0	75	0.80	1.25	(4)
Cypress		28.7	86	0.67	1.49	(1)
Douglas Fir	0% moisture	26.0	75	0.61	1.64	(4)
	0% "	34.0	75	0.67	1.49	(4)
	8% "	26.0	75	0.66	1.52	(4)
	8% "	34.0	75	0.75	1.33	(4)
	16% "	26.0	75	0.76	1.32	(4)
	16% "	34.0	75	0.82	1.22	(4)
Eastern Hemlock	0% moisture	22.0	75	0.60	1.67	(4)
	0% "	30.0	75	0.76	1.32	(4)
	8% "	22.0	75	0.63	1.59	(4)
	8% "	30.0	75	0.81	1.23	(4)
	16% "	22.0	75	0.67	1.49	(4)
	16% "	30.0	75	0.85	1.18	(4)

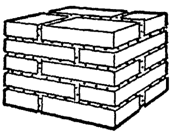
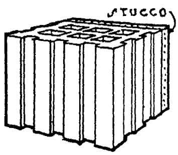
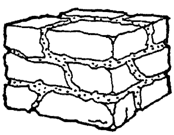
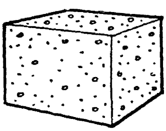
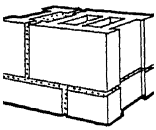
TABLE 2. CONDUCTIVITIES (k) AND CONDUCTANCES (C) OF BUILDING MATERIALS AND INSULATORS—Continued

The coefficients are expressed in Btu per hour per square foot per degree Fahrenheit per 1 in. thickness, unless otherwise indicated.

Material	Description	Density (Lb per Cu Ft)	Mean Temp. (Deg Fahr)	Conductivity (k) or Conductance (C)	Resistivity $\left(\frac{1}{k}\right)$ or Resistance (R)	Authority
WOODS—Continued						
HARD MAPLE	0% moisture	40.0	75	1.01	0.99	(4)
	0% “	46.0	75	1.05	0.95	(4)
	8% “	40.0	75	1.08	0.93	(4)
	8% “	46.0	75	1.13	0.89	(4)
	16% “	40.0	75	1.15	0.87	(4)
	16% “	46.0	75	1.21	0.83	(4)
LONGLEAF YELLOW PINE	0% moisture	30.0	75	0.76	1.32	(4)
	0% “	40.0	75	0.86	1.16	(4)
	8% “	30.0	75	0.83	1.21	(4)
	8% “	40.0	75	0.95	1.05	(4)
	16% “	30.0	75	0.89	1.12	(4)
	16% “	40.0	75	1.03	0.97	(4)
MAHOGANY		34.3	86	0.90	1.11	(1)
MAPLE		44.3	86	1.10	0.91	(1)
MAPLE OR OAK		----	----	1.15*	0.87	----
NORWAY PINE	0% moisture	22.0	75	0.62	1.61	(4)
	0% “	32.0	75	0.74	1.35	(4)
	8% “	22.0	75	0.68	1.47	(4)
	8% “	32.0	75	0.83	1.21	(4)
	16% “	22.0	75	0.74	1.35	(4)
	16% “	32.0	75	0.91	1.10	(4)
RED CYPRESS	0% moisture	22.0	75	0.67	1.49	(4)
	0% “	32.0	75	0.79	1.27	(4)
	8% “	22.0	75	0.71	1.41	(4)
	8% “	32.0	75	0.84	1.19	(4)
	16% “	22.0	75	0.74	1.35	(4)
	16% “	32.0	75	0.90	1.11	(4)
RED OAK	0% moisture	38.0	75	0.98	1.02	(4)
	0% “	48.0	75	1.18	0.85	(4)
	8% “	38.0	75	1.03	0.97	(4)
	8% “	48.0	75	1.24	0.81	(4)
	16% “	38.0	75	1.07	0.94	(4)
	16% “	48.0	75	1.29	0.78	(4)
SHORTLEAF YELLOW PINE	0% moisture	26.0	75	0.74	1.35	(4)
	0% “	36.0	75	0.91	1.10	(4)
	8% “	26.0	75	0.79	1.27	(4)
	8% “	36.0	75	0.97	1.03	(4)
	16% “	26.0	75	0.84	1.19	(4)
	16% “	36.0	75	1.04	0.96	(4)
SOFT ELM	0% moisture	28.0	75	0.73	1.37	(4)
	0% “	34.0	75	0.88	1.14	(4)
	8% “	28.0	75	0.77	1.30	(4)
	8% “	34.0	75	0.93	1.08	(4)
	16% “	28.0	75	0.81	1.24	(4)
	16% “	34.0	75	0.97	1.03	(4)
SOFT MAPLE	0% moisture	36.0	75	0.89	1.12	(4)
	0% “	42.0	75	0.95	1.05	(4)
	8% “	36.0	75	0.96	1.04	(4)
	8% “	42.0	75	1.02	0.98	(4)
	16% “	36.0	75	1.01	0.99	(4)
	16% “	42.0	75	1.09	0.92	(4)
SUGAR PINE	0% moisture	22.0	75	0.54	1.85	(4)
	0% “	28.0	75	0.64	1.56	(4)
	8% “	22.0	75	0.59	1.70	(4)
	8% “	28.0	75	0.71	1.41	(4)
	16% “	22.0	75	0.65	1.54	(4)
	16% “	28.0	75	0.78	1.28	(4)
VIRGINIA PINE		34.3	86	0.96	1.04	(1)
WEST COAST HEMLOCK	0% moisture	22.0	75	0.68	1.47	(4)
	0% “	30.0	75	0.79	1.27	(4)
	8% “	22.0	75	0.73	1.37	(4)
	8% “	30.0	75	0.85	1.18	(4)
	16% “	22.0	75	0.78	1.28	(4)
	16% “	30.0	75	0.91	1.10	(4)
WHITE PINE		31.2	86	0.78	1.28	(1)
YELLOW PINE		----	----	1.00	1.00	(3)
YELLOW PINE OR FIR		----	----	0.80*	1.25	----

TABLE 3. COEFFICIENTS OF TRANSMISSION (U) OF MASONRY WALLS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on a wind velocity of 15 mph.

TYPICAL CONSTRUCTION	TYPE OF WALL	THICKNESS OF MASONRY (INCHES)	WALL No.
	**Solid Brick** Based on 4-in. face brick and the remainder common brick.	8 12 16	**1** **2** **3**
	**Hollow Tile** Stucco Exterior Finish. The 8-in. and 10-in. tile figures are based on two cells in the direction of flow of heat. The 12-in. tile is based on three cells in the direction of flow of heat. The 16-in. tile consists of one 10-in. tile and one 6-in. tile each having two cells in the direction of heat flow.	8 10 12 16	**4** **5** **6** **7**
	**Limestone or Sandstone**	8 12 16 24	**8** **9** **10** **11**
	**Concrete** These figures may be used with sufficient accuracy for concrete walls with stucco exterior finish.	6 10 16 20	**12** **13** **14** **15**
	**Hollow Cinder Blocks** Based on one air cell in direction of heat flow.	8 12	**16** **17**
	Hollow Concrete Blocks Based on one air cell in direction of heat flow.	8 12	**18** **19**

[a]Computed from factors marked by * in Table 2.
[b]Based on the actual thickness of 2-in. furring strips.

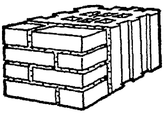
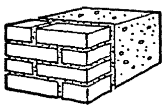
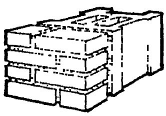
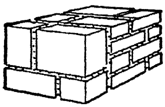
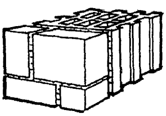
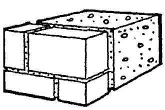
INTERIOR FINISH

Uninsulated Walls						Insulated Walls					
Plain walls—no interior finish	Plaster (½ in.) on walls	Plaster on wood lath—furred	Plaster (¾ in.) on metal lath—furred	Plaster (½ in.) on plaster board (⅜ in.)—furred	Decorated building board (½ in.) without plaster—furred	Plaster (½ in.) on rigid insulation (½ in.)—furred	Plaster (½ in.) on rigid insulation (1 in.)—furred	Plaster (½ in.) on corkboard (1½ in.) set in cement mortar (½ in.)	Plaster (¾ in.) on metal lath attached to furring strips—furred space (over ¾-in. wide) faced one side with bright aluminum foil	Plaster on metal lath attached to furring strips (2 in.[b])—rock wool fill (1⅝ in.[b])[c]	Plaster (¾ in.) on metal lath attached to furring strips (2 in.[b])—flexible insulation (½ in.) between furring strips (one air space)
A	B	C	D	E	F	G	H	I	J	K	L
0.50	0.46	0.30	0.32	0.30	0.23	0.22	0.16	0.14	0.23	0.12	0.20
0.36	0.34	0.24	0.25	0.24	0.19	0.19	0.14	0.12	0.19	0.11	0.17
0.28	0.27	0.20	0.21	0.20	0.17	0.16	0.13	0.11	0.17	0.10	0.15
0.40	0.37	0.26	0.27	0.26	0.20	0.20	0.15	0.13	0.20	0.11	0.18
0.39	0.37	0.26	0.27	0.26	0.20	0.19	0.15	0.13	0.20	0.11	0.18
0.30	0.29	0.22	0.22	0.22	0.17	0.17	0.13	0.12	0.17	0.10	0.16
0.25	0.24	0.19	0.19	0.19	0.15	0.15	0.12	0.11	0.15	0.097	0.14
0.71	0.64	0.37	0.39	0.37	0.26	0.25	0.18	0.15	0.26	0.13	0.23
0.58	0.53	0.33	0.34	0.33	0.24	0.23	0.17	0.14	0.24	0.13	0.21
0.49	0.45	0.30	0.31	0.30	0.22	0.22	0.16	0.14	0.22	0.12	0.20
0.37	0.35	0.25	0.26	0.25	0.20	0.19	0.15	0.13	0.20	0.11	0.18
0.79	0.70	0.39	0.42	0.39	0.27	0.26	0.19	0.16	0.27	0.13	0.23
0.62	0.57	0.34	0.37	0.34	0.25	0.24	0.18	0.15	0.25	0.13	0.22
0.48	0.44	0.29	0.31	0.29	0.22	0.21	0.16	0.14	0.22	0.12	0.20
0.41	0.39	0.27	0.28	0.27	0.21	0.20	0.15	0.13	0.21	0.12	0.18
0.42	0.39	0.27	0.28	0.27	0.21	0.20	0.16	0.13	0.21	0.12	0.19
0.37	0.35	0.25	0.26	0.25	0.19	0.19	0.15	0.13	0.19	0.11	0.17
0.56	0.52	0.32	0.34	0.32	0.24	0.23	0.17	0.14	0.24	0.12	0.21
0.49	0.46	0.30	0.32	0.30	0.23	0.22	0.16	0.14	0.23	0.12	0.20

[c]A waterproof membrane should be provided between the outer material and the insulation fill to prevent possible wetting by absorption and a subsequent lowering of efficiency.

TABLE 4. COEFFICIENTS OF TRANSMISSION (U) OF MASONRY WALLS WITH VARIOUS TYPES OF VENEERS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on a wind velocity of 15 mph.

TYPICAL CONSTRUCTION	TYPE OF WALL			WALL No.
	FACING	BACKING		
	4 in. **Brick Veneer**[d]	6 in. 8 in. 10 in. 12 in.	**Hollow Tile**[e]	**20** **21** **22** **23**
	4 in. **Brick Veneer**[d]	6 in. 10 in. 16 in.	**Concrete**	**24** **25** **26**
	4 in. **Brick Veneer**[d]	8 in. 12 in.	**Cinder Blocks**[e]	**27** **28**
	4 in. **Brick Veneer**[d]	8 in. 12 in.	**Concrete Blocks**[e]	**29** **30**
	4 in. **Cut-Stone Veneer**[d]	8 in. 12 in. 16 in.	**Common Brick**	**31** **32** **33**
	4 in. **Cut-Stone Veneer**[d]	6 in. 8 in. 10 in. 12 in.	**Hollow Tile**[e]	**34** **35** **36** **37**
	4 in. **Cut-Stone Veneer**[d]	6 in. 10 in. 16 in.	**Concrete**	**38** **39** **40**

[a]Computed from factors marked by * in Table 2.
[b]Based on the actual thickness of 2-in. furring strips.
[c]The 6-in., 8-in. and 10-in. tile figures are based on two cells in the direction of heat flow. The 12-in. tile is based on three cells in the direction of heat flow.

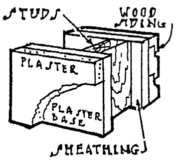
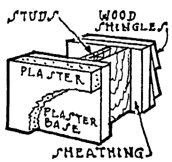
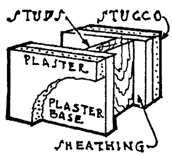
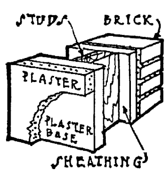
INTERIOR FINISH

Uninsulated Walls					Insulated Walls						
Plain walls—no interior finish	Plaster (½ in.) on walls	Plaster on wood lath—furred	Plaster (¾ in.) on metal lath—furred	Plaster (½ in.) on plaster board (⅜ in.)—furred	No plaster—decorated rigid or building board interior finish (½ in.)—furred	Plaster (½ in.) on rigid insulation (½ in.)—furred	Plaster (½ in.) on rigid insulation (1 in.)—furred	Plaster on corkboard (1½ in.) set in cement mortar (½ in.)	Plaster on metal lath (¾ in.) attached to furring strips—furred space (over ¾-in. wide) faced one side with bright aluminum foil	Plaster (¾ in.) on metal lath attached to furring strips (2 in.[b])—rock wool fill (1⅝ in.[b])[f]	Plaster (¾ in.) on metal lath attached to furring strips (2 in.[b])—flexible insulation (½ in.) between furring strips (one air space)
A	B	C	D	E	F	G	H	I	J	K	L
0.36 0.34 0.34 0.27	0.34 0.33 0.32 0.26	0.24 0.24 0.23 0.20	0.25 0.25 0.24 0.21	0.24 0.24 0.23 0.20	0.19 0.19 0.19 0.16	0.19 0.18 0.18 0.16	0.16 0.14 0.14 0.13	0.13 0.12 0.12 0.11	0.19 0.19 0.19 0.16	0.11 0.11 0.11 0.10	0.17 0.17 0.17 0.15
0.57 0.48 0.39	0.53 0.45 0.37	0.33 0.30 0.26	0.35 0.31 0.27	0.33 0.30 0.26	0.24 0.22 0.20	0.23 0.22 0.19	0.17 0.16 0.15	0.14 0.14 0.13	0.24 0.22 0.20	0.13 0.12 0.11	0.21 0.20 0.18
0.35 0.31	0.33 0.30	0.24 0.22	0.25 0.23	0.24 0.22	0.19 0.18	0.18 0.17	0.14 0.14	0.12 0.12	0.19 0.18	0.11 0.11	0.17 0.16
0.44 0.40	0.42 0.38	0.28 0.26	0.30 0.28	0.28 0.26	0.21 0.20	0.21 0.20	0.16 0.15	0.13 0.13	0.21 0.20	0.12 0.11	0.19 0.18
0.37 0.28 0.23	0.35 0.27 0.22	0.25 0.21 0.18	0.26 0.21 0.18	0.25 0.21 0.18	0.19 0.17 0.15	0.19 0.16 0.14	0.15 0.13 0.12	0.13 0.12 0.11	0.19 0.17 0.15	0.11 0.10 0.095	0.17 0.15 0.14
0.37 0.36 0.35 0.28	0.35 0.34 0.33 0.26	0.25 0.24 0.24 0.20	0.26 0.25 0.25 0.21	0.25 0.24 0.24 0.20	0.20 0.19 0.19 0.17	0.19 0.19 0.18 0.16	0.15 0.15 0.14 0.13	0.13 0.13 0.12 0.11	0.20 0.19 0.19 0.17	0.11 0.11 0.11 0.10	0.18 0.17 0.17 0.15
0.61 0.51 0.41	0.56 0.47 0.38	0.34 0.31 0.26	0.36 0.32 0.28	0.34 0.31 0.26	0.25 0.23 0.20	0.24 0.22 0.20	0.18 0.17 0.15	0.15 0.14 0.13	0.25 0.23 0.21	0.13 0.12 0.11	0.22 0.20 0.18

[d]Calculations include cement mortar (½ in.) between veneer or facing and backing.
[e]Based on one air cell in direction of heat flow.
[f]A waterproof membrane should be provided between the outer material and the insulation fill to prevent possible wetting by absorption and a subsequent lowering of efficiency.

TABLE 5. COEFFICIENTS OF TRANSMISSION (U) OF VARIOUS TYPES OF FRAME CONSTRUCTION[a]

These coefficients are expressed in Btu per hour per square foot pe degree Fahrenheit difference in temperature between the air on the tw sides, and are based on a wind velocity of 15 mph.

TYPICAL CONSTRUCTION	EXTERIOR FINISH	TYPE OF SHEATHING	
	**Wood Siding or Clapboard**	**1 in. Wood**[d]	
		; in. Rigid Insulation	
		½ in. Plaster Board	**43**
	**Wood Shingles**	**1 in. Wood**[d]	**44**
		½ in. Rigid Insulation[e]	**45**
		½ in. Plaster Board[e]	**46**
	**Stucco**	**1 in. Wood**[d]	**47**
		½ in. Rigid Insulation	**48**
		½ in. Plaster Board	**49**
	**Brick[f] Veneer**	**1 in. Wood**[d]	**50**
		½ in. Rigid Insulation	**51**
		½ in. Plaster Board	**52**

[a]Computed from factors marked by * in Table 2.

[b]These coefficients may also be used with sufficient accuracy for plaster on wood lath or plaster on plaster board.

[e]Based on the actual width of 2 by 4 studding, namely, 3⅝ in.

INTERIOR FINISH

No Insulation Between Studding							Insulation Between Studding		
Plaster on wood lath on studding	Plaster (¾ in.) on metal lath on studding	Plaster (½ in.) on plaster board (⅜ in.) on studding	Plaster (½ in.) on rigid insulation (½ in.) on studding	Plaster (½ in.) on rigid insulation (1 in.) on studding	Plaster (½ in.) on corkboard (1½ in.) on studding	No plaster—decorated rigid or building board interior finish (½ in.)	Plaster (¾ in.) on metal lath—stud space faced one side with bright aluminum foil	Plaster (¾ in.) on metal lath[b] on studding—rock wool fill (3⅝ in.[c]) between studding[g]	Plaster (¾ in.) on metal lath[b] on studding—flexible insulation (½ in.) between studding and in contact with sheathing
A	B	C	D	E	F	G	H	I	J
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.23	0.24	0.23	0.18	0.14	0.11	0.18	0.18	0.060	0.17
0.31	0.33	0.31	0.22	0.17	0.13	0.23	0.23	0.064	0.20
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.19	0.20	0.19	0.15	0.12	0.10	0.16	0.16	0.057	0.14
0.24	0.25	0.24	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.30	0.31	0.30	0.22	0.16	0.12	0.22	0.22	0.064	0.20
0.27	0.29	0.27	0.20	0.16	0.12	0.21	0.21	0.062	0.19
0.40	0.43	0.40	0.26	0.19	0.14	0.28	0.28	0.067	0.24
0.27	0.28	0.27	0.20	0.15	0.12	0.21	0.21	0.062	0.18
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.20	0.061	0.18
0.35	0.37	0.35	0.24	0.18	0.13	0.25	0.25	0.066	0.22

[d]Yellow pine or fir—actual thickness about 25/32 in.

[e]Furring strips between wood shingles and sheathing.

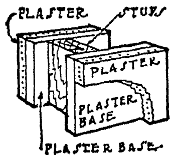
[f]Small air space and mortar between building paper and brick veneer neglected.

[g]A waterproof membrane should be provided between the outer material and the insulation fill to prevent possible wetting by absorption and a subsequent lowering of efficiency.

Table 6. Coefficients of Transmission (U) of Frame Interior Walls and Partitions[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



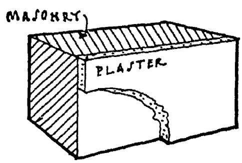
Type of Wall	Wall No.	Single Partition (Finish on One Side of Studding)	Double Partition (Finished on Both Sides of Studding): Air Space Between Studding	Flaked Gypsum Fill[b] Between Studding	Rock Wool Fill[b] Between Studding	½-in. Flexible Insulation Between Studding (One Air Space)	Stud Space Faced One Side with Bright Aluminum Foil
		A	B	C	D	E	F
Wood Lath and Plaster On Studding	53	0.62	0.34	0.11	0.065	0.21	0.24
Metal Lath and Plaster[c] On Studding	54	0.69	0.39	0.11	0.066	0.23	0.26
Plaster Board (⅜ in.) and Plaster[d] On Studding	55	0.61	0.34	0.10	0.065	0.21	0.24
½ in. Rigid Insulation and Plaster[d] On Studding	56	0.35	0.18	0.083	0.056	0.14	0.15
1 in. Rigid Insulation and Plaster[d] On Studding	57	0.23	0.12	0.066	0.048	0.097	0.10
1½ in. Corkboard and Plaster[d] On Studding	58	0.16	0.081	0.052	0.040	0.070	0.073
2 in. Corkboard and Plaster[d] On Studding	59	0.12	0.063	0.045	0.035	0.057	0.059

[a]Computed from factors marked by * in Table 2.
[b]Thickness assumed 3⅝ in.
[c]Plaster on metal lath assumed ¾-in. thick.
[d]Plaster assumed ½-in. thick.

Table 7. Coefficients of Transmission (U) of Masonry Partitions[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



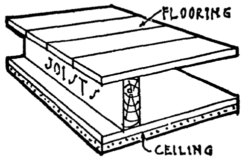
Type of Wall	No.	Plain Walls (No Plaster)	Walls Plastered on One Side	Walls Plastered on Both Sides
		A	B	C
4-in. Hollow Clay Tile	60	0.45	0.42	0.40
4-in. Common Brick	61	0.50	0.46	0.43
4-in. Hollow Gypsum Tile	62	0.30	0.28	0.27
2-in. Solid Plaster	63	....	....	0.53

[a]Computed from factors marked by * in Table 2.

TABLE 8. COEFFICIENTS OF TRANSMISSION (U) OF FRAME CONSTRUCTION FLOORS AND CEILINGS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



TYPE OF CEILING	INSULATION BETWEEN JOISTS	No.	TYPE OF FLOORING: No Flooring	Yellow Pine Flooring[b] on Joists	Yellow Pine Flooring on Rigid Insulation (½ in.) on Joists	Maple or Oak Flooring[c] on Yellow Pine Sub-Flooring[b] on Joists	¼-in. Battleship Linoleum on Yellow Pine Flooring[b]
			A	B	C	D	E
No Ceiling	None	1	....	0.46	0.27	0.34	0.34
Metal Lath and Plaster (¾ in.)	None	2	0.69	0.30	0.21	0.25	0.25
Wood Lath and Plaster	None	3	0.62	0.28	0.20	0.24	0.24
Plaster Board (⅜ in.) and Plaster (½ in.)	None	4	0.61	0.28	0.20	0.24	0.23
Rigid Insulation (½ in.) and Plaster (½ in.)	None	5	0.35	0.21	0.16	0.18	0.18
Metal Lath and Plaster	Flexible[d] Insulation (½ in.)	6	0.24	0.16	0.13	0.15	0.15
Metal Lath and Plaster	Rigid Insulation[d] (½ in.)	7	0.26	0.17	0.14	0.15	0.15
Metal Lath and Plaster	Bright Aluminum Foil[e]	8	0.59	0.22	0.16	0.19	0.19
Metal Lath and Plaster	Rock Wool Fill (3⅝ in.)	9	0.067	0.063	0.058	0.060	0.060
Corkboard (1½ in.) and Plaster (½ in.)	None	10	0.16	0.12	0.10	0.11	0.11
Corkboard (2 in.) and Plaster (½ in.)	None	11	0.12	0.10	0.087	0.094	0.094

[a]Computed from factors marked by * in Table 2.

[b]Thickness assumed to be 25/32 in.

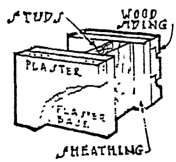
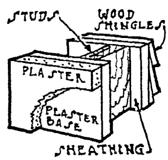
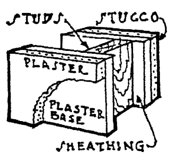
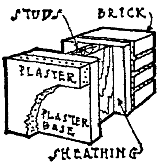
[c]Thickness assumed to be 13/16 in.

[d]Based on one air space with no flooring, and two air spaces with flooring. The value of U will be the same if insulation is applied to under side of joists and separated from lath and plaster ceiling by 1-in. furring strips.

[e]Air space faced on one side with bright aluminum foil.

TABLE 5. COEFFICIENTS OF TRANSMISSION (U) OF VARIOUS TYPES OF FRAME CONSTRUCTION[a]

These coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on a wind velocity of 15 mph.

TYPICAL CONSTRUCTION	EXTERIOR FINISH	TYPE OF SHEATHING	WALL No.
	**Wood Siding or Clapboard**	1 in. Wood[d]	**41**
		½ in. Rigid Insulation	**42**
		½ in. Plaster Board	**43**
	**Wood Shingles**	1 in. Wood[d]	**44**
		½ in. Rigid Insulation[e]	**45**
		½ in. Plaster Board[e]	**46**
	**Stucco**	1 in. Wood[d]	**47**
		½ in. Rigid Insulation	**48**
		½ in. Plaster Board	**49**
	**Brick[f] Veneer**	1 in. Wood[d]	**50**
		½ in. Rigid Insulation	**51**
		½ in. Plaster Board	**52**

[a]Computed from factors marked by * in Table 2.

[b]These coefficients may also be used with sufficient accuracy for plaster on wood lath or plaster on plaster board.

[e]Based on the actual width of 2 by 4 studding, namely, 3⅝ in.

INTERIOR FINISH

No Insulation Between Studding							Insulation Between Studding		
Plaster on wood lath on studding	Plaster (¾ in.) on metal lath on studding	Plaster (½ in.) on plaster board (⅜ in.) on studding	Plaster (½ in.) on rigid insulation (½ in.) on studding	Plaster (½ in.) on rigid insulation (1 in.) on studding	Plaster (½ in.) on corkboard (1½ in.) on studding	No plaster—decorated rigid or building board interior finish (½ in.)	Plaster (¾ in.) on metal lath—stud space faced one side with bright aluminum foil	Plaster (¾ in.) on metal lath[b] on studding—rock wool fill (3⅝ in.[c]) between studding[g]	Plaster (¾ in.) on metal lath[b] on studding—flexible insulation (½ in.) between studding and in contact with sheathing
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.23	0.24	0.23	0.18	0.14	0.11	0.18	0.18	0.060	0.17
0.31	0.33	0.31	0.22	0.17	0.13	0.23	0.23	0.064	0.20
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.19	0.20	0.19	0.15	0.12	0.10	0.16	0.16	0.057	0.14
0.24	0.25	0.24	0.19	0.15	0.11	0.19	0.19	0.061	0.17
0.30	0.31	0.30	0.22	0.16	0.12	0.22	0.22	0.064	0.20
0.27	0.29	0.27	0.20	0.16	0.12	0.21	0.21	0.062	0.19
0.40	0.43	0.40	0.26	0.19	0.14	0.28	0.28	0.067	0.24
0.27	0.28	0.27	0.20	0.15	0.12	0.21	0.21	0.062	0.18
0.25	0.26	0.25	0.19	0.15	0.11	0.19	0.20	0.061	0.18
0.35	0.37	0.35	0.24	0.18	0.13	0.25	0.25	0.066	0.22

[d]Yellow pine or fir—actual thickness about ²⁵⁄₃₂ in.

[e]Furring strips between wood shingles and sheathing.

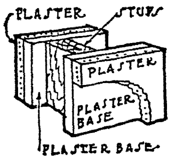
[f]Small air space and mortar between building paper and brick veneer neglected.

[g]A waterproof membrane should be provided between the outer material and the insulation fill to prevent possible wetting by absorption and a subsequent lowering of efficiency.

TABLE 6. COEFFICIENTS OF TRANSMISSION (U) OF FRAME INTERIOR WALLS AND PARTITIONS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



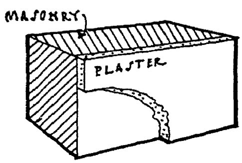
TYPICAL CONSTRUCTION	WALL No.	SINGLE PARTITION (FINISH ON ONE SIDE OF STUDDING)	DOUBLE PARTITION (FINISHED ON BOTH SIDES OF STUDDING)				
			Air Space Between Studding	Flaked Gypsum Fill[b] Between Studding	Rock Wool Fill[b] Between Studding	½-in. Flexible Insulation Between Studding (One Air Space)	Stud Space Faced One Side with Bright Aluminum Foil
TYPE OF WALL		A	B	C	D	E	F
Wood Lath and Plaster On Studding	53	0.62	0.34	0.11	0.065	0.21	0.24
Metal Lath and Plaster[c] On Studding	54	0.69	0.39	0.11	0.066	0.23	0.26
Plaster Board (⅜ in.) and Plaster[d] On Studding	55	0.61	0.34	0.10	0.065	0.21	0.24
½ in. Rigid Insulation and Plaster[d] On Studding	56	0.35	0.18	0.083	0.056	0.14	0.15
1 in. Rigid Insulation and Plaster[d] On Studding	57	0.23	0.12	0.066	0.048	0.097	0.10
1½ in. Corkboard and Plaster[d] On Studding	58	0.16	0.081	0.052	0.040	0.070	0.073
2 in. Corkboard and Plaster[d] On Studding	59	0.12	0.063	0.045	0.035	0.057	0.059

[a]Computed from factors marked by * in Table 2.
[b]Thickness assumed 3⅝ in.
[c]Plaster on metal lath assumed [illegible]-in. thick.
[d]Plaster assumed ½-in. thick.

TABLE 7. COEFFICIENTS OF TRANSMISSION (U) OF MASONRY PARTITIONS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



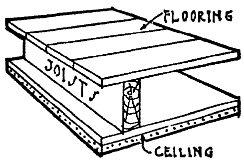
TYPICAL CONSTRUCTION	No.	PLAIN WALLS (NO PLASTER)	WALLS PLASTERED ON ONE SIDE	WALLS PLASTERED ON BOTH SIDES
TYPE OF WALL		A	B	C
4-in. Hollow Clay Tile	60	0.45	0.42	0.40
4-in. Common Brick	61	0.50	0.46	0.43
4-in. Hollow Gypsum Tile	62	0.30	0.28	0.27
2-in. Solid Plaster	63	--------	--------	0.53

[a]Computed from factors marked by * in Table 2.

TABLE 8. COEFFICIENTS OF TRANSMISSION (U) OF FRAME CONSTRUCTION FLOORS AND CEILINGS[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



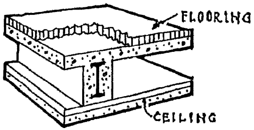
Type of Ceiling	Insulation Between Joists	No.	Type of Flooring: No Flooring	Yellow Pine Flooring[b] on Joists	Yellow Pine Flooring on Rigid Insulation (½ in.) on Joists	Maple or Oak Flooring[c] on Yellow Pine Sub-Flooring[b] on Joists	¼-in. Battleship Linoleum on Yellow Pine Flooring[b]
			A	B	C	D	E
No Ceiling	**None**	**1**	....	0.46	0.27	0.34	0.34
Metal Lath and Plaster (¾ in.)	**None**	**2**	0.69	0.30	0.21	0.25	0.25
Wood Lath and Plaster	**None**	**3**	0.62	0.28	0.20	0.24	0.24
Plaster Board (⅜ in.) and Plaster (½ in.)	**None**	**4**	0.61	0.28	0.20	0.24	0.23
Rigid Insulation (½ in.) and Plaster (½ in.)	**None**	**5**	0.35	0.21	0.16	0.18	0.18
Metal Lath and Plaster	**Flexible[d] Insulation (½ in.)**	**6**	0.24	0.16	0.13	0.15	0.15
Metal Lath and Plaster	**Rigid Insulation[d] (½ in.)**	**7**	0.26	0.17	0.14	0.15	0.15
Metal Lath and Plaster	**Bright Aluminum Foil[e]**	**8**	0.59	0.22	0.16	0.19	0.19
Metal Lath and Plaster	**Rock Wool Fill (3⅝ in.)**	**9**	0.067	0.063	0.058	0.060	0.060
Corkboard (1½ in.) and Plaster (½ in.)	**None**	**10**	0.16	0.12	0.10	0.11	0.11
Corkboard (2 in.) and Plaster (½ in.)	**None**	**11**	0.12	0.10	0.087	0.094	0.094

[a]Computed from factors marked by * in Table 2.
[b]Thickness assumed to be 25/32 in.
[c]Thickness assumed to be 13/16 in.
[d]Based on one air space with no flooring, and two air spaces with flooring. The value of U will be the same if insulation is applied to under side of joists and separated from lath and plaster ceiling by 1-in. furring strips.
[e]Air space faced on one side with bright aluminum foil.

Table 9. Coefficients of Transmission (U) of Concrete Construction Floors and Ceilings[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on still air (no wind) conditions on both sides.

TYPICAL CONSTRUCTION



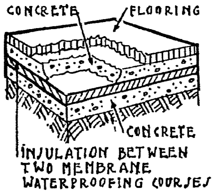
Type of Ceiling	Thickness of Concrete (Inches)	No.	TYPE OF FLOORING: No Flooring (Concrete Bare)[b]	Yellow Pine Flooring[c] on Wood Sleepers Embedded in Concrete[d]	Maple or Oak Flooring[e] on Yellow Pine Sub-Flooring[c] on Wood Sleepers Embedded in Concrete	Tile or Terrazzo[f] Flooring on Concrete	1/4-in. Battleship Linoleum Directly on Concrete
			A	B	C	D	E
No Ceiling	4	1	0.65	0.40	0.31	0.61	0.44
	6	2	0.59	0.37	0.30	0.56	0.41
	8	3	0.53	0.35	0.28	0.51	0.38
	10	4	0.49	0.33	0.27	0.47	0.36
½ in. Plaster Applied Directly to Under Side of Concrete	4	5	0.59	0.38	0.30	0.56	0.41
	6	6	0.54	0.35	0.28	0.52	0.38
	8	7	0.50	0.33	0.27	0.47	0.36
	10	8	0.45	0.32	0.26	0.44	0.34
Suspended or Furred Metal Lath and Plaster (¾ in.) Ceiling	4	9	0.37	0.28	0.23	0.36	0.29
	6	10	0.35	0.26	0.22	0.34	0.28
	8	11	0.33	0.25	0.21	0.32	0.27
	10	12	0.32	0.24	0.21	0.31	0.25
Suspended or Furred Ceiling of Plaster Board (⅜ in.) and Plaster (½ in.)	4	13	0.35	0.26	0.22	0.34	0.28
	6	14	0.33	0.25	0.21	0.32	0.26
	8	15	0.31	0.24	0.21	0.30	0.25
	10	16	0.30	0.23	0.20	0.29	0.24
Suspended or Furred Ceiling of Rigid Insulation (½ in.) and Plaster (½ in.)	4	17	0.24	0.20	0.17	0.24	0.21
	6	18	0.23	0.19	0.17	0.23	0.20
	8	19	0.22	0.18	0.16	0.22	0.19
	10	20	0.22	0.18	0.16	0.21	0.19
Plaster (½ in.) on Corkboard (1½ in.) Set in Cement Mortar (½ in.) on Concrete	4	21	0.15	0.13	0.12	0.14	0.14
	6	22	0.14	0.13	0.12	0.14	0.13
	8	23	0.14	0.12	0.11	0.14	0.13
	10	24	0.14	0.12	0.11	0.14	0.13

[a] Computed from factors marked by * in Table 2.
[b] The figures in Column A may be used with sufficient accuracy for concrete floors covered with carpet.
[c] Thickness of yellow pine flooring assumed to be 25/32 in.
[d] The figures in Column B may be used with sufficient accuracy for maple or oak flooring[e] applied directly over the concrete on wood sleepers.
[e] Thickness of maple or oak flooring assumed to be 13/16 in.
[f] Thickness of tile or terrazzo assumed 1 in.

Table 10. Coefficients of Transmission (U) of Concrete Floors on Ground with Various Types of Finish Flooring[a, e]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the ground and the air over the floor, and are based on still air (no wind) conditions.

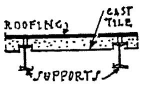
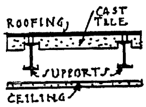
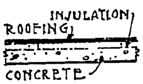
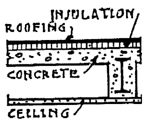
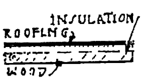
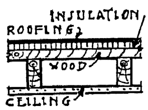
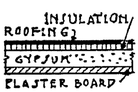
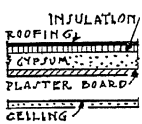
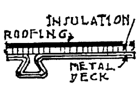
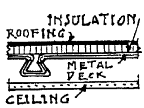
TYPICAL CONSTRUCTION



Type and Thickness of Insulation	Thickness of Concrete (Inches)	No.	Type of Finish Flooring: No Flooring (Concrete Bare)	Yellow Pine Flooring[b] on Wood Sleepers Resting on Concrete	Maple or Oak Flooring[c] on Yellow Pine Sub-Flooring on Wood Sleepers Resting on Concrete	Tile or Terrazzo[d] on Concrete	¼-in. Battleship Linoleum Directly on Concrete
			A	B	C	D	E
None	4	1	1.07	0.35	0.28	0.98	0.60
	6	2	0.90	0.33	0.27	0.84	0.54
	8	3	0.79	0.32	0.26	0.74	0.50
	10	4	0.70	0.30	0.25	0.66	0.46
None[e]	4	5	0.66	0.29	0.24	0.63	0.44
	8	6	0.54	0.27	0.23	0.52	0.39
1 in. Rigid Insulation[e]	4	7	0.22	0.16	0.14	0.22	0.19
1 in. Rigid Insulation[e]	8	8	0.21	0.15	0.13	0.20	0.18
2 in. Corkboard[e]	4	9	0.12	0.099	0.093	0.12	0.11
2 in. Corkboard[e]	8	10	0.12	0.096	0.090	0.12	0.11

[a]Computed from factors marked by * in Table 2.
[b]Assumed 25/32 in. thick.
[c]Assumed 13/16 in. thick.
[d]Assumed 1 in. thick.
[e]The figures for Nos. 5 to 10, inclusive, include 3-in. cinder concrete placed directly on the ground. The insulation is applied between the cinder concrete and the stone concrete. Usually the insulation is protected on both sides by a waterproof membrane, but this is not considered in the calculations.

TABLE 11. COEFFICIENTS OF TRANSMISSION (*U*) OF VARIOUS TYPES OF FLAT ROOFS COVERED WITH BUILT-UP ROOFING[a]

TYPICAL CONSTRUCTION: WITHOUT CEILINGS	TYPICAL CONSTRUCTION: WITH METAL LATH AND PLASTER CEILINGS[d]	TYPE OF ROOF DECK	THICKNESS OF ROOF DECK (INCHES)	No.
		**Precast Cement Tile**	1⅝	1
		**Concrete** **Concrete** **Concrete**	2 4 6	2 3 4
		**Wood** **Wood** **Wood** **Wood**	1[b] 1½[b] 2[b] 4[b]	5 6 7 8
		**Gypsum Fiber Concrete**[c] **(2 in.) on Plaster Board** (⅜ in.) **Gypsum Fiber Concrete**[c] **(3 in.) on Plaster Board** (⅜ in.) **Gypsum Fiber Concrete**[c] (2 in.) **on Rigid Insulation Board** (½ in.) **Gypsum Fiber Concrete**[c] (2 in.) **on Rigid Insulation Board** (1 in.)	2⅜ 3⅜ 2½ 3	9 10 11 12
		**Flat Metal Roofs** Coefficient of transmission of bare corrugated iron (no roofing) is 1.50 Btu per hour per square foot of projected area per degree Fahrenheit difference in temperature, based on an outside wind velocity of 15 mph.	......	13

[a]Computed from factors marked by * in Table 2.
[b]Nominal thicknesses specified—actual thicknesses used in calculations.
[c]Gypsum fiber concrete—87½ per cent gypsum, 12½ per cent wood fiber.

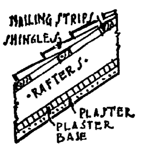
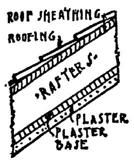
Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on an outside wind velocity of 15 mph.

WITHOUT CEILING—UNDER SIDE OF ROOF EXPOSED								WITH METAL LATH AND PLASTER CEILINGS[d]							
No Insulation	Rigid Insulation (½ in.)	Rigid Insulation (1 in.)	Rigid Insulation (1½ in.)	Rigid Insulation (2 in.)	Corkboard (1 in.)	Corkboard (1½ in.)	Corkboard (2 in.)	No Insulation	Rigid Insulation (½ in.)	Rigid Insulation (1 in.)	Rigid Insulation (1½ in.)	Rigid Insulation (2 in.)	Corkboard (1 in.)	Corkboard (1½ in.)	Corkboard (2 in.)
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
0.84	0.37	0.24	0.18	0.14	0.22	0.16	0.13	0.43	0.26	0.19	0.15	0.12	0.18	0.14	0.11
0.82	0.37	0.24	0.17	0.14	0.22	0.16	0.13	0.42	0.26	0.19	0.15	0.12	0.18	0.14	0.11
0.72	0.34	0.23	0.17	0.13	0.21	0.16	0.12	0.40	0.25	0.18	0.14	0.12	0.17	0.13	0.11
0.64	0.33	0.22	0.16	0.13	0.21	0.15	0.12	0.37	0.24	0.18	0.14	0.11	0.17	0.13	0.11
0.49	0.28	0.20	0.15	0.12	0.19	0.14	0.12	0.32	0.21	0.16	0.13	0.11	0.15	0.12	0.10
0.37	0.24	0.18	0.14	0.11	0.17	0.13	0.11	0.26	0.19	0.15	0.12	0.10	0.14	0.11	0.095
0.32	0.22	0.16	0.13	0.11	0.16	0.12	0.10	0.24	0.17	0.14	0.11	0.097	0.13	0.11	0.092
0.23	0.17	0.14	0.11	0.096	0.13	0.11	0.091	0.18	0.14	0.12	0.10	0.087	0.11	0.096	0.082
0.40	0.25	0.18	0.14	0.12	0.17	0.13	0.11	0.27	0.19	0.15	0.12	0.10	0.14	0.12	0.097
0.32	0.22	0.16	0.13	0.11	0.15	0.12	0.10	0.23	0.17	0.14	0.11	0.097	0.13	0.11	0.091
0.26	0.19	0.15	0.12	0.10	0.14	0.11	0.10	0.20	0.16	0.13	0.11	0.09	0.12	0.10	0.087
0.19	0.15	0.12	0.10	0.09	0.12	0.10	0.08	0.16	0.13	0.11	0.09	0.08	0.10	0.09	0.077
0.95	0.39	0.25	0.18	0.14	0.23	0.17	0.13	0.46	0.27	0.19	0.15	0.12	0.18	0.14	0.11

[d]These coefficients may be used with sufficient accuracy for wood lath and plaster, or plaster board and plaster ceilings. It is assumed that there is an air space between the under side of the roof deck and the upper side of the ceiling.

Table 12. Coefficients of Transmission (U) of Pitched Roofs[a]

Coefficients are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air on the two sides, and are based on an outside wind velocity of 15 mph.

Typical Construction	Type of Roofing and Roof Sheathing	Insulation between Roof Rafters	No.	Type of Ceiling (Applied Directly to Roof Rafters): No Ceiling (Rafters Exposed)	Metal Lath and Plaster (¾ in.)	Plaster Board (⅜ in.) and Plaster (½ in.)	Wood Lath and Plaster	Rigid Insulation (½ in.)	Rigid Insulation (½ in.) and Plaster (½ in.)	Rigid Insulation (1 in.) and Plaster (½ in.)	Corkboard (1½ in.) and Plaster (½ in.)	Corkboard (2 in.) and Plaster (½ in.)
				A	B	C	D	E	F	G	H	I
	Wood Shingles on Wood Strips[b]	None	1	0.46	0.30	0.29	0.29	0.22	0.21	0.16	0.12	0.10
		½ in. Flexible[c]	2	....	0.17	0.16	0.16	0.14	0.13	0.11	0.091	0.079
		1 in. Flexible[c]	3	....	0.13	0.12	0.12	0.11	0.11	0.092	0.078	0.069
		Bright Aluminum Foil[g]	4	....	0.22	0.21	0.21	0.17	0.17	0.13	0.10	0.085
		3⅝ in. Rock Wool[e]	5	....	0.063	0.062	0.062	0.058	0.058	0.053	0.048	0.044
	Asphalt Shingles, Rigid Asbestos Shingles, Composition Roofing, or Slate or Tile Roofing[d] on Wood Sheathing[f]	None	6	0.56	0.34	0.32	0.32	0.24	0.23	0.17	0.13	0.11
		½ in. Flexible[c]	7	....	0.18	0.17	0.17	0.14	0.14	0.12	0.094	0.089
		1 in. Flexible[c]	8	....	0.13	0.13	0.13	0.11	0.11	0.095	0.080	0.071
		Bright Aluminum Foil[g]	9	....	0.24	0.23	0.23	0.18	0.18	0.14	0.11	0.093
		3⅝ in. Rock Wool[e]	10	....	0.065	0.064	0.064	0.060	0.059	0.054	0.049	0.045

[a]Computed from factors marked by * in Table 2. Nos. 6 to 10, inclusive, based on ½-in. thick slate.
[b]Based on 1 in. by 4 in. strips spaced 2 in.
[c]Figures based on two air spaces. Insulation may also be applied to under side of roof rafters with furring strips between.
[d]Roofing felt between roof sheathing and slate or tile neglected in calculations.
[e]Assumed 3⅝ in. thick based on the actual width of 2 in. by 4 in. rafters.
[f]Sheathing assumed 25/32 in. thick.
[g]Air space faced on one side with bright aluminum foil.

TABLE 13. COEFFICIENTS OF TRANSMISSION (U) OF DOORS, WINDOWS AND SKYLIGHTS

Coefficients are based on a wind velocity of 15 mph, and are expressed in Btu per hour per square foot per degree Fahrenheit difference in temperature between the air inside and outside of the door, window or skylight

A. Windows and Skylights

	U
Single	1.13[a, c]
Double	0.45[a]
Triple	0.281[a]

B. Solid Wood Doors[b, c]

Nominal Thickness Inches	Actual Thickness Inches	U
1	25/32	0.69
1¼	1 1/16	0.59
1½	1 5/16	0.52
1¾	1⅜	0.51
2	1⅝	0.46
2½	2⅛	0.38
3	2⅝	0.33

[a]See *Heating, Ventilating and Air Conditioning*, by Harding and Willard, revised edition, 1932.
[b]Computed using $C = 1.15$ for wood; $f_i = 1.65$ and $f_o = 6.0$.
[c]It is sufficiently accurate to use the same coefficient of transmission for doors containing thin wood panels as that of single panes of glass, namely, 1.13 Btu per hour per square foot per degree difference between inside and outside air temperatures.

Table 14. Conductivities (*k*) of Typical Insulating Materials by Trade Name

The coefficients are expressed in B.t.u. per hour per square foot per degree Fahrenheit per 1-inch thickness

Insulation	Description	*k*
Cabot's Quilt	Quilt form paper covered	.25
Eagle Picher	Wool type—Loose form	.27
	Wool type—Bat form	.27
	Wool type—Blanket form	.27
Red Top	Wool type—Bat form	27
Johns Manville	Wool type—Bat form	.27
	Rigid form, ½-inch	.33
	Rigid form, 1-inch	.33
	Flexible form, ½-inch	.27
	Flexible form, 1-inch	.27
Balsam Wool	Wool type—Blanket form	.25
Ruberoid Pipe Covering	85% Magnesia, *100°F	.425
	85% Magnesia, *200°F	.465
	85% Magnesia, *300°F	.505
	85% Magnesia, *400°F	.550
	Supercell (14–16 laminations per inch)	
	Supercell *100°F	.408
	Supercell *200°F	.479
	Supercell *300°F	.550
	Supercell *400°F	.620
	Watocell (8 plies per inch)	
	Watocell *100°F	.480
	Watocell *200°F	.555
	Watocell *300°F	630
	Watocell *400°F	.705
	Air Cell (4 plies per inch)	
	Air Cell *100°F	.530
	Air Cell *200°F	.650
	Air Cell *300°F	.770
	Air Cell *400°F	.890
	*Mean temperature. (The mean of the inner and outer surface temperatures of the insulation.)	
Masonite	Rigid type	.321
Red Top	Wool type	.266
	Weatherwood board	.33
	Weatherwood lath	.33
	Plank	.33
	Tile	.33
Burgess Acousti-Pad	Sound-absorbing material for ducts	.246
Homasote	Rigid type—building board	355
	Rigid type—plaster backing	.37
Insulite	Rigid type—building board ¾-inch	.327
	Rigid type—plaster backing	.327
	Rigid type—Biltrite sheathing	.36
	Rigid type—plank, B-B joints, ½-inch	.327
	Rigid type—integral roof insulation, ½-inch	.33
	Rigid type—cold storage form, 1-inch	.28
	Rigid type—tile B.B.	.327
	Sealdslab, 1-inch	.326
	Rigid type—asphalted-roof ½-inch	346
	Fiberock—loose	.26
	Fiberock—granulated	26
	Fiberock—bats	.26
Alfol	Bright aluminum foil. Conductances (c) and Resistances (R) can be found in Table 2, page 112.	
Celotex	Rigid type—building board	.33
	Rigid type—plaster backing	.33
Dry Zero	Pliable slab form	.246
Ozite	Hair blanket type	.246
Insulex	Cellular Gypsum type	.35
Balsa Wood	Wood type	.33
Temlok	Rigid type—plaster backing	.34
	Rigid—building board	.34
Nu-Wood	Board form	.324
	Interior finish plank	.324
	Interior finish wainscot	.324
	Insulation lath	.324
	Roof insulation—board	.35
	Wood insulation—board	.35
	Cold storage insulation	.35
Thermax	Rigid type	.46
Thermofelt	Felted type	.28
	Wool type	.35
Sil-O-Cel	Powdered diatomaceous earth	.31
Thermofil	Powdered form gypsum	.52
Eureka	Corkboard type	.32
Armstrong Cork	Rigid type	
	7 lbs. per cu. ft., 90° mean temp.	.27
	8 lbs. per cu. ft., 90° mean temp.	.28
	9 lbs. per cu. ft., 90° mean temp.	.29
	10 lbs. per cu. ft., 90° mean temp.	.30
	11 lbs. per cu. ft., 90° mean temp.	.31
	15 lbs. per cu. ft., 90° mean temp.	.35
	7 lbs. per cu. ft., 80° mean temp.	.265
	10 lbs. per cu. ft., 80° mean temp.	.295
	7 lbs. per cu. ft., 50° mean temp.	.255
	8 lbs. per cu. ft., 50° mean temp.	.265
	9 lbs. per cu. ft., 50° mean temp.	.275
	17 lbs. per cu. ft., 50° mean temp.	.355

Note: The basic method of comparing insulating materials is by comparison of their "Conductivity." However, as these materials are generally available in several thicknesses, and are used in combination with other materials, it is the measurement of the actual installation of these materials which provides a correct measure of wall, roof, floor, or partition as to its heat-transmitting properties.

Thus no accurate comparisons can be made between items in Table 14. This is further explained on page 107.

***Table 15. Coefficients of Transmission (*U*) of Bright Aluminum Foil in Various Wall Types**

Wall Type	Layers of Foil	Over-All Heat Transmittance
Frame	3	.08
Frame	2	.10
Frame	1	.13
Frame	0	.26
†Brick veneer, 1-inch air space	3	.07
Brick veneer, 1-inch air space	2	.08
Brick veneer, 1-inch air space	1	.12
Brick veneer, 1-inch air space	0	.22
‡Concrete block	3	.08
Concrete block	2	.10
Concrete block	1	.15
Concrete block	0	.32
Stucco	3	.08
Stucco	2	.09
Stucco	1	.14
Stucco	0	.30
Brick veneer, 4-inch, on 8-inch tile	3	.08
Brick veneer, 4-inch, on 8-inch tile	2	.09
Brick veneer, 4-inch, on 8-inch tile	1	.13
Brick veneer, 4-inch, on 8-inch tile	0	.24
Stucco on 8-inch tile	3	.08
Stucco on 8-inch tile	2	.09
Stucco on 8-inch tile	1	.13
Stucco on 8-inch tile	0	.26
‡8-inch concrete walls	3	.09
8-inch concrete walls	2	.10
8-inch concrete walls	1	.16
8-inch concrete walls	0	.36
Brick (8-inch) walls	3	.08
Brick (8-inch) walls	2	.09
Brick (8-inch) walls	1	.14
Brick (8-inch) walls	0	.30

*Data, Courtesy of Alfol Company.
†Air space between sheathing and bricks.
‡Insulation between furring strips. Strips against masonry.

*Table 16. Typical *U* Over-all Transmission for Various Constructions Using Rigid and Wool Insulations

Type of Exterior	Type of Sheathing		No Insulation Between Studs				3⅝ Inches Red Top Between Studs		
			Wood Lath and Plaster	Insulating Rock Lath and Plaster	½-inch Weather-wood, Lath and Plaster	1 inch Weather-wood Lath and Plaster	Wood Lath and Plaster	½-inch Weather-wood, Lath and Plaster	1 inch Weather-wood, Lath and Plaster
			A	B	C	D	E	F	G
Wood Siding or Clap-boards	Wood	1	.25	.19	.19	.15	.060	.056	.052
	½" Weather-wood sheathing	2	.23	.18	.18	.14	.059	.055	.050
	¾" Weather-wood sheathing	3	.20	.16	.16	.13	.057	.053	.048
	1" Weather-wood sheathing	4	.17	.14	.14	.12	.054	.051	.047
	Insulating Gyplap	5	.22	.21	.17	.14	......	......	......
		6	......	......	......	......	......	......	......
Wood Shingles	Wood	7	.25	.19	.19	.15	.060	.056	.052
	½" Weather-wood sheathing	8	.19	.15	.15	.12	.056	.052	.048
	¾" Weather-wood sheathing	9	.17	.13	.13	.11	.054	.050	.046
	1" Weather-wood sheathing	10	.15	.12	.12	.10	.051	.048	.045
	Insulating Gyplap	11	.18	.17	.15	.13	......	......	......
		12	......	......	......	......	......	......	......
Stucco	Wood	13	.30	.22	.22	.19	.063	.058	.056
	½" Weather-wood sheathing	14	.27	.20	.20	.17	.061	.057	.054
	¾" Weather-wood sheathing	15	.22	.17	.17	.15	.058	.054	.052
	1" Weather-wood sheathing	16	.19	.15	.15	.14	.056	.052	.050
	Insulating Gyplap	17	.27	.25	.20	.17	......	......	......
		18	......	......	......	......	......	......	......
Brick Veneer	Wood	19	.27	.20	.20	.15	.061	.057	.052
	½" Weather-wood sheathing	20	.25	.19	.19	.15	.060	.056	.052
	¾" Weather-wood sheathing	21	.21	.17	.17	.13	.057	.054	.049
	1" Weather-wood sheathing	22	.18	.15	.15	.12	.055	.052	.048
	Insulating Gyplap	23	.24	.23	.18	.15	......	......	......
		24	......	......	......	......	......	......	......

*Data by Courtesy U. S. Gypsum Co.

*Table 17. Approximate Fuel Savings in Dwelling Houses

Expressed in per cent of fuel which would have been required for a similar house without insulation or weatherstripping.

	Saving in Per Cent
No insulation—weatherstripped	15 to 20
Same with double (storm) windows	25 to 30
½-inch Insulation—not weatherstripped	20 to 30
½-inch Insulation—weatherstripped	About 40
½-inch Insulation—with double windows	About 50
1-inch Insulation—not weatherstripped	30 to 40
1-inch Insulation—weatherstripped	About 50
1-inch Insulation—with double windows	About 60

Expressed in per cent of fuel which would have been required for a similar house without insulation but with weatherstripping.

	Saving in Per Cent
Double windows, no insulation	10 to 15
½-inch Insulation only	25 to 35
½-inch Insulation—with double windows	40 to 45
1-inch Ins lation only	35 to 45
1-inch Insulation with double windows	50 to 55

*U. S. Bureau of Standards.

Computed Coefficients. In order to clarify the use of the formulas previously given for calculating transmission coefficients, and to show how the coefficient tables are used, the following example is presented. The reader should be very certain that he understands the complete calculation, because errors made in applying the principles are costly.

Example. Figure the coefficient of transmission U of an 8-inch brick wall having plaster $\frac{1}{2}$-inch thick applied directly to the inside surface of the wall without lathing. The outside course of brick is face brick and the inside common brick. Wind velocity is assumed, as usual, at 15 miles per hour. Thickness of each brick course is 4 inches. The inside and outside surface coefficients are assumed to be 1.65 and 6.00, respectively.

The solution of such a problem requires one of the basic formulas, and upon studying the formulas we see that formula (3) page 98 fits the conditions of our problem; a solid wall (no air space) made up of three different materials.

First write formula (3)

$$U=\frac{}{\frac{1}{f_i}+\frac{x_1}{k_1}+\frac{x_2}{k_2}+\frac{x_3}{k_3}+\frac{1}{f_o}}$$

now substitute these values in the formula

$$\frac{1}{f_i}=\frac{1}{1.65}$$

$$\frac{x_1}{k_1}=\frac{4.0}{9.20}$$

$$\frac{x_2}{k_2}=\frac{4.0}{5.0}$$ All of these k values can be found in Table 2

$$\frac{x_3}{k_3}=\frac{0.5}{3.3}$$

$$\frac{1}{f_o}=\frac{1}{6.0}$$

We know that $f_i=1.65$ because the problem states that the inside surface coefficient is 1.65. The x_1 and k_1 represent thickness and coefficient for the face brick. The thickness being 4 inches, then $x_1=4.0$. The first page of Table 2 shows that the coefficient or conductivity for face brick is 9.20. So $\frac{x_1}{k_1}=\frac{4}{9.20}$. The second x and second k represent the thickness and coefficient for common brick. This is 4 inches wide, so $x_2=4.0$. Table 2 shows that the coefficient for common brick is 5.0, so $k_2=5\ 0$. The third x and third k represent the thickness and the coefficient of plaster. The plaster thickness is $\frac{1}{2}$ inch, so $x_3=0.5$. The bottom of the third page of Table 2 shows that plaster has a coefficient of 3.3, so $k_3=3.3$. The outside surface coefficient was given as 6.00, so $f_o=6.00$.

Thus the formula becomes:

$$U=\frac{1}{\frac{1}{1.65}+\frac{4.0}{9.20}+\frac{4.0}{5.0}+\frac{0.5}{3.3}+\frac{1}{6.0}} \qquad \textit{Ans. } U=0.46$$

Note: There are two methods of solving the above equation. Method 1: it is assumed that the reader understands the procedure of adding fractions, which is necessary before the denominator in the formula can be added. Find a least common denominator, express all fractions in terms of this denominator and add. Then divide 1 by the result. Method 2: the various fractions can be changed to decimals by dividing their numerators by their denominators. The quotients then become denominators under the numerator of 1. Then divide 1 by the total of the denominators to find U.

The answer for this example is 0.46 B.t.u. per hour per square foot per degree F. difference in temperature between the air on the two sides.

The coefficients in the tables were determined by calculations similar to those shown in the example just solved, using fundamental formulas (2) to (7) and the values of k (or C_a), f_i, f_o and a indicated in Table 2 by asterisks. In computing heat transmission coefficients of floors laid directly on the ground (Table 10), only one surface coefficient, f_i, is used. For example, the value of U for a 1-inch yellow pine floor (actual thickness, $\frac{25}{32}$-inch) placed directly on 6-inch concrete on the ground, is determined as follows:

$$U=\frac{1}{\frac{1}{1.65}+\frac{0.781}{0.80}+\frac{6.0}{12.0}}=0.48$$ B.t.u. per hour per square foot per degree difference in temperature between the ground and the air immediately above the floor.

The thicknesses in inches upon which the coefficients in Tables 3 to 13, inclusive, are based, are as follows:

Construction	Thickness Inches
Brick veneer	4
Plaster and metal lath	$\frac{3}{4}$
Plaster (on wood lath, plasterboard, rigid insulation, board form, or corkboard)	$\frac{1}{2}$
Slate (roofing)	$\frac{1}{2}$
Stucco on wire mesh reinforcing	1
Tar and gravel or slag-surfaced built-up roofing	$\frac{3}{8}$
1-inch lumber (S-2-S)	$\frac{25}{32}$
$1\frac{1}{2}$-inch lumber (S-2-S)	$1\frac{5}{16}$
2-inch lumber (S-2-S)	$1\frac{5}{8}$
$2\frac{1}{2}$-inch lumber (S-2-S)	$2\frac{1}{8}$
3-inch lumber (S-2-S)	$2\frac{5}{8}$
4-inch lumber (S-2-S)	$3\frac{5}{8}$
Finish flooring (maple or oak)	$\frac{13}{16}$

Solid brick walls are based on 4-inch face brick and the remainder common brick. Stucco is assumed to be 1 inch thick on masonry

walls. Where metal lath and plaster are specified, the metal lath is neglected.

Rigid insulation refers to the so-called board form which may be used structurally, as for sheathing. Flexible insulation refers to the blankets, quilts, or semi-rigid types of insulation.

Actual, rather than nominal thicknesses of lumber are used in the computations. The computations for roofs of wood shingles applied over wood stripping are based on 1×4-inch wood strips, spaced 2 inches apart. Since no reliable figures are available concerning the conductivity of Spanish and French clay roofing tile, of which there are many varieties, the figures for such types of roofs were taken the same as for slate roofs, as it is probable that the values of U for these two types of roofs will compare favorably.

The coefficients of transmission of the pitched roofs in Table 12 apply where the roof is over a heated attic or top floor so the heat passes directly through the roof structure including whatever finish is applied to the underside of the roof rafters.

Note: In Chapter VIII will be found examples that show how to calculate U values for walls, roofs, etc., not insulated, partly insulated, and fully insulated. It is not advisable to turn to Chapter VIII at this time because of the intervening material. However, when Chapter VIII is studied, in its turn, the reader will find ample examples of the methods of calculating U values.

Combined Coefficients. It often happens that the attic space in residences is unheated, and the roofs are generally pitched to some degree. When heat loss is to be calculated where such ordinary conditions are met, the combined coefficients for roof and ceiling are considered in one formula. This saves time and tends to give more accurate results.

$$U=\frac{U_r\times U_{ce}}{n\times U_r+U_{ce}} \tag{8}$$

Where

U_r = coefficient of transmission of the roof

U_{ce} = coefficient of transmission of ceiling

n = ratio of the roof area to the area of ceiling

This formula assumes the calculation per square foot of area.

To use this formula for good results a correction factor must be kept in mind. The amount of heat transferred through an air space is proportional to the difference of the fourth powers of the absolute

temperatures of the surfaces enclosing the air space. Thus a greater amount of heat is absorbed or emitted by radiation by the surfaces enclosing an unheated attic than by the surfaces of a wall or ceiling in a room under still air conditions, where the surrounding objects are only slightly higher in temperature than the inside surfaces of walls, etc. To explain further, the average coefficient of a surface in still air is 1.65 B.t.u. per hour per square foot per degree F. compared to the average coefficient of an air space in an outside wall of 1.10 B.t.u. per hour per square foot per degree F. difference between the two areas. An air space coefficient of 1.10 is about the same as a surface coefficient of 2.20 for each of the two surfaces enclosing the air space when the over-all transmission is computed by using the coefficients of the two surfaces enclosing the space, instead of the coefficient of the air space itself. So, when we determine the value of U_r and U_{ce}, the coefficients should be increased to allow for the added amount of heat transferred and a coefficient of 2.20 may be used for each area or surface.

If there are no dormers, windows, or vertical wall areas, combined coefficients may be used to determine heat loss, but the coefficients should be multiplied by roof area and not ceiling area. If the attic space has windows, ventilators, etc., which tend to keep the enclosed air at or near the outside temperatures, the roof should be left out of the calculations and only the ceiling and floor construction and area be taken into consideration. Then coefficients of Tables 8 or 9 are to be used. In case there are no dormers, windows, etc., the attic space temperature can be assumed as being the average between the inside and outside temperatures.

From this discussion it is evident that ordinary good judgment is all that is necessary and where very good results are required, maximum conditions should always be assumed in order to bring about some degree of safety factor. When insulation enters into the calculations, even more care must be exercised because of the added cost involved in the structure. Insulation, while being an agent to promote comfortable occupancy of a residence, also aims to effect economy of fuel and power. Therefore, if design calculations were inaccurate, almost a total loss in both comfort and economy factors might be experienced.

When heat losses are being calculated for walls or partitions

between two rooms or areas, one being heated and the other not, we can generally assume the unheated space to be at a temperature of 32°F. if it is closed and not open to the weather. If such a room or space is open in any way, as by windows or door left open or by ventilators, then we assume its temperature to be the same as the outside temperature.

In figuring losses through first floors, the basement is assumed, in extreme cases, to be 32°F. The basement, however, is usually only a few degrees cooler in the winter than the first floor areas because of the heating equipment, pipe runs, etc., so that the designer may assume its temperature as being considerably above 32°F. if economy of insulation is a basic principle in the construction, etc.

Walls or partitions next to an entry way or vestibule are calculated as to heat loss by assuming a temperature of 32°F. unless the entry or vestibule is likely to be open a great deal, in which case the outside temperature should be assumed for it.

Air Leakage. Residences and buildings in general cannot be built practically so that leakage or infiltration does not take place. The mere fact that windows and doors can be opened and closed indicates that they must be fitted with considerable tolerance, thus leaving what we call cracks around their perimeters. Such cracks are not too small for infiltration or leakage of air. Also, buildings become a little porous with age, due to shrinkages, poorly fitted structural parts, etc. On a windy and cold winter day it is possible to feel the cold air coming in around a window or door. In poorly constructed buildings this passage of air becomes even more pronounced. Therefore such infiltrations and losses must be taken into account.

These losses or infiltrations are caused by the wind and by temperature differences. Without wind very little infiltration would take place in a well-built structure, but, as wind is almost continual, we must include it in our calculations. Wind strikes a building on one or two sides at a time. Its pressure causes infiltration of air through cracks and other porous parts. This air, getting into a heated space, has a decided influence tending to lower the temperature, and so must be provided for in heat loss calculations and in the selection of a heating plant capable of adequately heating the space in question.

Another cause of infiltration is the difference in temperature between air inside and outside. The difference is a matter of density. In tall buildings a chimney effect is caused, especially in stair wells, elevator shafts, etc.

We are not able to estimate very accurately the heat loss by infiltration from these sources because of varying wind velocities, changing of wind direction, changing of temperatures, etc. Therefore we must adopt a means of calculating that will be as accurate as possible, and in addition build our buildings as tight and sound as we can.

Table 18. Infiltration through Walls*

Expressed in cubic feet per square foot per hour[a]

Wind velocity, miles per hour	5	10	15	20	25	30
8½-inch brick wall, plain	1.75	4.20	7.85	12.2	18.6	22.9
8½-inch brick wall, plastered	0.017	0.037	0.066	0.107	0.161	0.236
13-inch brick wall, plain	1.44	3.92	7.48	11.6	16.3	21.2
13-inch brick wall, plastered	0.005	0.013	0.025	0.043	0.067	0.097
Frame wall, with lath and plaster[b]	0.03	0.07	0.13	0.18	0.23	0.26

[a]The values in this table are 20 per cent less than test values, to allow for building up of pressure in rooms, and are based on test data reported in A. S. H. V. E. research papers entitled, "Air Infiltration through Various Types of Brick Wall Construction," and "Air Infiltration through Various Types of Wood Frame Construction."

[b]Wall construction: bevel siding painted or cedar shingles, sheathing, building paper, wood lath, and 3 coats gypsum plaster.

Leakage through Walls. In Table 18 are shown several common types of wall constructions.

The brick walls are assumed to represent walls poorly constructed. This means poor quality or porous brick, poor quality (non-cement) mortar, and poor workmanship. Where good hard bricks and cement mortar are used in the walls and careful work is done, the infiltration will be about one-third the values shown in Table 18. Then if equally good plastering is applied, the leakage is reduced 95 per cent more. Good plastering composed of three coats and carefully sealed at the baseboard, almost does away with infiltration through brick and frame walls. For such results the plaster should be carried all the way down to the flooring or rough flooring, leaving only a nailing strip for the baseboard separating the plaster areas. This is an important point if wall infiltration is to be neglected or even assumed as practically nothing. The note *a* in Table 18 refers to laboratory testing as compared to actual conditions.

*Courtesy A. S. H. V. E. Guide, 1936.

In actual conditions there is a slight air pressure built up inside the space being considered, which cuts down the infiltration caused by wind pressure.

Proper supervision by an architect or building superintendent is a great advantage insofar as leakage is concerned, because, by being ever watchful, mistakes, carelessness, and other factors in poor workmanship can be avoided and leakage prevented. Large amounts of insulation can be offset by poor workmanship, loose fitting, etc.

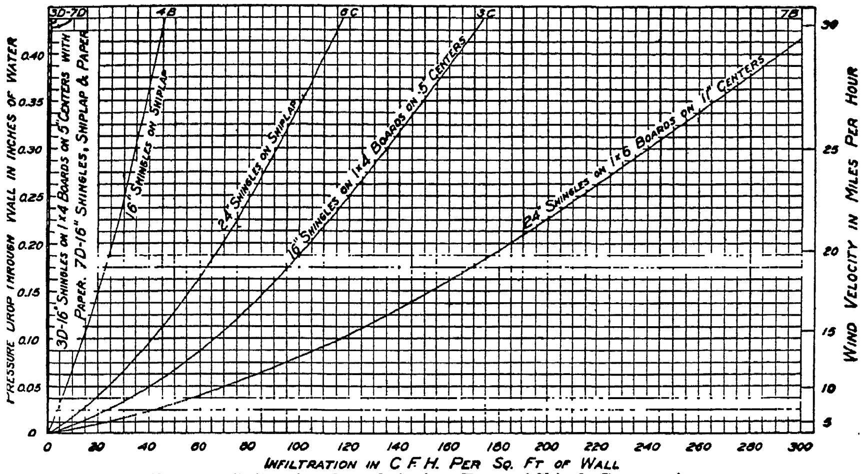


Fig. 104. Infiltration through Various Types of Shingle Construction
Courtesy of A.S.H.V.E. Guide, 1936, Chapter 6

Fig. 104 illustrates infiltration for various types of shingle construction. The graph is self-explanatory. It should be pointed out that a good quality building paper means a great deal. Even a good plaster job can be offset to a large degree if a poor building paper is used between shingles or siding and the sheathing in a frame building.

Fig. 105 shows the infiltration losses through walls used for various farm buildings. It will be noted that good quality construction and good quality materials mean a saving in heat loss by infiltration.

In both Figs. 104 and 105 the infiltration figures should be multiplied by 80 per cent—in other words only 80 per cent of the values shown should be used—because the figures were made from laboratory experiments and under actual conditions the loss is not quite so much, due to inside pressures, as elsewhere explained.

Leakage through Windows. Table 19 gives the amounts of infiltration for various types of windows, expressed in cubic feet of crack per hour.

The total length of crack for a double-hung window is obtained by adding the lengths of the two vertical sides, the top, the bottom, and the meeting rail. The table shows results for poorly fitted windows as well as for well constructed ones, and the designer must assure himself of good construction in new work if he is to use latter

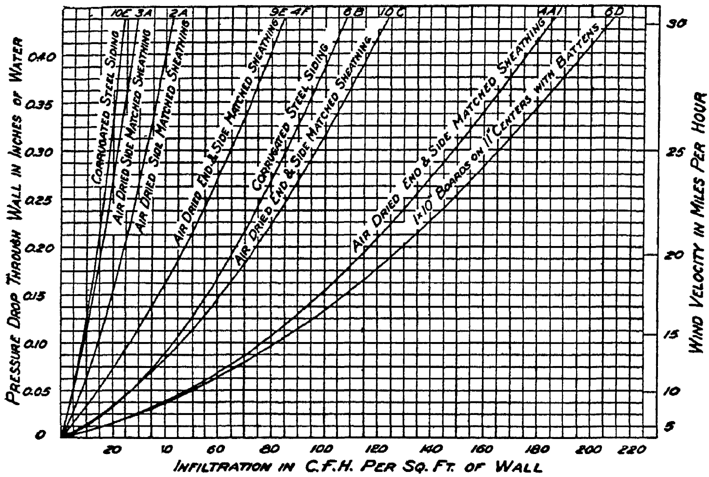


Fig. 105. Infiltration through Single Surface Walls Used in Farm and Other Shelter Buildings
Courtesy of A.S.H.V.E. Guide, 1935, Chapter 6

values. For old structures, the values for poorly fitted windows are used unless considerable work is to be done to repair and tighten up. Table 19 shows infiltration values for *unlocked* windows, as tests by A. S. H. V. E. have shown that the leakage for locked windows is greater than for unlocked. In order that low infiltration values may be applied to them, windows must be snug fitting, free from warping, well puttied, well painted, and have frames in equally good condition. Any deviation from these specifications should place the window in the poorly fitted class to avoid costly errors in heat-loss calculations. Windows in existing buildings should be examined and rigid specifications insisted upon in new structures.

Casement windows of wood construction are in the same class

as a well-fitted double-hung window. If metal pivoted sash is used the total crack is considered to be equal to the perimeter (distance around) of that portion of the sash that is movable. Steel windows have so little leakage that it can be neglected if good workmanship is assured; otherwise the infiltration values equal to industrial pivoted sash in Table 19 should be used.

Leakage through Doors. If a door is well fitted (this means properly tight and having a stop) the same values per foot of crack may be used as for a poorly fitted double-hung window. If weather-

Table 19. Infiltration through Windows*

Expressed in cubic feet per foot of crack per hour[a]

Type of Window	Remarks	Wind Velocity, Miles per Hour					
		5	10	15	20	25	30
Double-Hung Wood Sash Windows (Unlocked)	Around frame in masonry wall—not calked[b]	3.3	8.2	14.0	20.2	27.2	34.6
	Around frame in masonry wall—calked[b]...	0.5	1.5	2.6	3.8	4.8	5.8
	Around frame in wood frame construction[b]..	2.2	6.2	10.8	16.6	23.0	30.3
	Total for average window, non-weatherstripped, $\frac{1}{16}$-inch crack and $\frac{3}{64}$-inch clearance[c]. Includes wood frame leakage[d]....	6.6	21.4	39.3	59.3	80.0	103.7
	Ditto, weatherstripped[d]................	4.3	15.5	23.6	35.5	48.6	63.4
	Total for poorly fitted window, non-weatherstripped, $\frac{3}{32}$-inch crack and $\frac{3}{32}$-inch clearance[e]. Includes wood frame leakage[d]...	26.9	69.0	110.5	153.9	199.2	249.4
	Ditto, weatherstripped[d]................	5.9	18.9	34.1	51.4	70.5	91.5
Double-Hung Metal Windows[f]	Non-weatherstripped, locked............	20	45	70	96	125	154
	Non-weatherstripped, unlocked...........	20	47	74	104	137	170
	Weatherstripped, unlocked..............	6	19	32	46	60	76
Rolled Section Steel Sash Windows[k]	Industrial pivoted,[g] $\frac{1}{16}$-inch crack.........	52	108	176	244	304	372
	Architectural projected,[h] $\frac{3}{64}$-inch crack....	20	52	88	116	152	208
	Residential casement,[i] $\frac{1}{32}$-inch crack......	14	32	52	76	100	128
	Heavy casement section, projected,[j] $\frac{1}{32}$-inch crack............................	8	24	38	54	72	96
Hollow metal, vertically pivoted window[f]...............		30	88	145	186	221	242

[a]The values given in this table are 20 per cent less than test values to allow for building up of pressure in rooms.

[b]The values given for frame leakage are per foot of sash perimeter as determined for double-hung wood windows. Some of the frame leakage in masonry walls originates in the brick wall itself and cannot be prevented by calking. For the additional reason that calking is not done perfectly and deteriorates with time, it is considered advisable to choose the masonry frame leakage values for calked frames as the average determined by the calked and not-calked tests.

[c]The fit of the average double-hung wood window was determined as $\frac{1}{16}$-inch crack and $\frac{3}{64}$-inch clearance, by measurements on approximately 600 windows under heating season conditions.

[d]The values given are the totals for the window opening per foot of sash perimeter and include frame leakage and so-called *elsewhere* leakage. The frame leakage values included are for wood frame construction but apply as well to masonry construction, assuming a 50 per cent efficiency of frame calking.

[e]A $\frac{3}{32}$-inch crack and clearance represents a poorly fitted window, much poorer than average.

[f]Windows tested in place in building.

[g]Industrial pivoted window generally used in industrial buildings. Ventilators horizontally pivoted at center or slightly above, lower part swinging out.

[h]Architectural projected made of same sections as industrial pivoted except that outside framing member is heavier, and refinements inweathering and hardware. Used in semi-monumental buildings such as schools. Ventilators swing in or out and are balanced on side arms.

[i]Of same design and section shapes as so-called heavy section casement but of lighter weight.

[j]Made of heavy sections. Ventilators swing in or out and stay set at any degree of opening.

[k]With reasonable care in installation, leakage at contacts where windows are attached to steel framework and at mullions is negligible. With $\frac{3}{64}$-inch crack, representing poor installation, leakage at contact with steel framework is about one-third, and at mullions about one-sixth of that given for industrial pivoted windows in the table.

*Courtesy A. S. H. V. E. Guide, 1936.

stripping is used values may be cut 50 per cent. To merit this rating, doors should not be warped or cracked. If a door has glass in it, the glass should be figured the same as a well-fitted double-hung window, with some cut in values if well fitted and not to be opened. If a door is being opened and closed considerably, its infiltration value should be multiplied by three or four or more, according to how much it is open.

Storm Sash. Storm sash do not effect a very great actual saving insofar as reducing the amount of infiltration is concerned where the window proper is well made and well fitted. One thing they do accomplish is to cause an air space between themselves and the regular window which has a tendency to cut down the heat loss by transmission, but the actual amount is not a matter of record so storm sash must be considered merely a safety factor on heat loss calculations made in the regular manner. Storm sash do have the proven effect of stopping frost from forming on the windows.

Storm sash to be most effective must be securely fitted into place using wool weather strip, and no provision made for opening the window or storm sash. Such a condition would be all right, where there is air conditioning, because no windows would ever be open, but otherwise such storm sash would not be desirable.

In the case of poorly constructed or poorly fitted windows, storm sash can be counted on to reduce the infiltration by almost half, even where the storm sash is so arranged as to provide for its being opened as desired.

From Fig. 106 it will be noted that in the case of good window construction the use of storm sash effects very little saving at wind velocities of 15 to 20 miles per hour. Lines *A* and *B* represent a window with and without storm sash and if these lines are noted at a point representing 15 to 20 miles per hour wind pressure, it will be seen that very little difference exists. Fig. 106 also shows the saving indicated, by the difference between lines *A* and *D*. It will be seen that at ordinary wind velocities of 15 to 20 miles per hour the saving, while more than for loose storm sash, still is not great.

We conclude, therefore, that storm sash in general create but little saving unless the window is not to be opened; also that storm sash create a little saving in loss by transmission, and prevent frost on the windows. In many cases the cost of storm sash is too much

as compared to the good derived, and careful attention should be given this matter. The infiltration figures in Fig. 106 can be used in all calculations. Where window crack is upward of $\frac{1}{8}$ inch, the figures for infiltration in Fig. 106 should at least be doubled.

In using such graphs as Fig. 106, account must be taken of the actual wind velocity. To base calculations on exact velocities would be difficult because of the changing velocities from day to day.

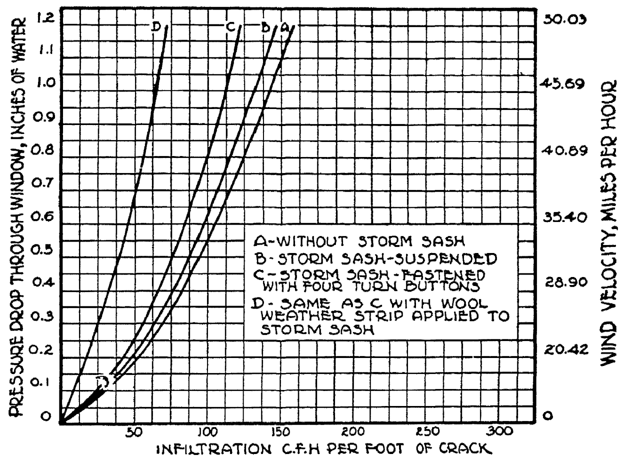


Fig. 106. Infiltration through Sash Perimeter of Window, with and without Storm Sash—$\frac{5}{64}$-inch Crack and $\frac{1}{32}$-inch Clearance
Courtesy of A.S.H.V.E. Guide, 1936. Chapter 6

Therefore some average velocity should be ascertained. In Chapter VI, Table 25, Column *E*, are given average wind velocities for principal cities throughout the United States, and in the same table, Column *F*, prevailing wind direction is stated. These figures can be used fairly accurately because they were compiled from Weather Bureau records. If a certain locality for which calculations are being made is not mentioned in the table, then select the city nearest the point in question.

The actual amount of crack to consider in infiltration calculations can be less than the computed linear amount, due to the fact that if wind strikes a building on the north side it causes cold air to enter through the cracks, but at the same time causes *outward* leakage of room air on the south side. With this theory in mind

we could cut down the amount of crack in a given problem. However, the amount of crack should not be cut below one-half the actual amount. No harm will be done by including the actual amount of crack instead of taking advantage of the theory just explained.

Some designers roughly estimate the amount of leakage around windows and doors by assuming a certain number of air changes per hour as shown in Table 20.

Table 20. Air Changes per Hour Exclusive of Ventilation

Room or Building	Air Changes per Hour	Room or Building	Air Changes per Hour
Entrance halls	2 or 3	Factories	2
Living rooms	1 or 2	Rooms—1 side exposed	1
Dining rooms	1 or 2	Rooms—2 sides exposed	1
Bath rooms	2	Rooms—3 sides exposed	2
Ordinary stores	1	Rooms—4 sides exposed	2
Drug stores	2 or 3	Rooms having no windows	½
Churches	2		

If Table 20 values are used, they should check closely with calculations made by actually figuring the total length of crack and using Table 19.

Several methods for figuring leakage have been explained in the order of their accuracy. The choice of the one to be used depends on actual conditions and must be decided by the designer.

Tall Buildings. Chimney effects, etc., produce heads that add to wind effects on lower floors and subtract from it on the upper floors. Thus the wind velocity in tall buildings becomes very complicated. To avoid confusion formulas (9) and (10) are presented.

$$M_e=\sqrt{M^2-1.75a} \qquad (9)$$

$$M_e=\sqrt{M^2+1.75b} \qquad (10)$$

Where

M_e=equivalent wind velocity to be used with Tables 18 and 19.

M=wind velocity upon which infiltration would be determined if temperature difference were disregarded.

a=distance of windows being considered from mid-height of building if *above* mid-height.

b=distance if *below* mid-height.

Heat Equivalent of Air Entering by Infiltration. As cold outside air enters a room by infiltration it must be heated. The heat required to accomplish this is calculated by formula (**11**).

$$\mathrm{H}_i=0.24Qd(t-t_o) \qquad (11)$$

Where

H_i = B.t.u. per hour required for heating air leaking into the building from outside temperature, t_o to inside temperature, t.

Q = cubic feet of air entering per hour at inside temperature, t.

d = density (pounds per cubic foot) of air at inside temperature, t.

t = inside temperature at proper level.

t_o = outside air temperature for which heating system is designed.

0.24 = specific heat of air.

It is accurate enough to take $d=0.075$ pound, in which case the equation reduces to

$$H_i=0.018Q(t-t_o) \tag{12}$$

Note: Illustrative problems on the material covered in this chapter, in addition to the problems given throughout this chapter, can be found in Chapter VIII. The reader is advised to consider all these problems at the time he studies Chapter VIII in its regular turn, at which time he can refer back to this chapter as required.

PRACTICE PROBLEMS

If the reader finds he has difficulty in solving these problems at this point in the text, he is advised to put them aside until he has completed his study of Chapter VIII.

1. Assume a wind velocity of 15 miles per hour and a building 18 stories high (1 story = 10 feet). Calculate the effective wind pressure at the ground floor and at the 15th floor.

Ans. 19.6 (ground floor)
11.0 (15th floor)

2. A room contains three plain double-hung windows 2 feet 8 inches by 5 feet 6 inches, with $\frac{1}{16}$-inch crack and $\frac{3}{64}$-inch clearance. Assume wind velocity of 20 miles per hour and a temperature difference of 75°F. Calculate maximum heat loss due to infiltration.

Ans. 4561 B.t.u. per hour

3. (a) Find the infiltration through a wall with 16-inch shingles on 1-inch by 4-inch boards and a 20-mile per hour wind. (b) Also give pressure drop through the wall.

Ans. (a) 102 c.f.h. per square foot of wall
(b) 0.193

4. What will be the infiltration through air-dried end and side-matched sheathing for wind at 15 miles per hour?

Ans. 50 c.f.h. per square foot of wall

5. Using an infiltration figure of 59.3 cubic feet per foot of crack per hour, what will be the heat requirement in a building with total crack (all windows and doors) of 180 feet, if the wind velocity is 15 miles per hour, the outside temperature 0°F., and the inside temperature 70°F. Use the method of solution where half the amount of crack is used and formula (12). *Ans.* 6724.6 B.t.u.

6. A solid 12-inch common brick wall is finished on the inside with $\frac{1}{2}$-inch insulation plaster base, and $\frac{1}{2}$ inch of plaster; the plaster base is furred 1 inch from the brick; k for insulating material is .34. Calculate the over-all coefficient U. Assume $f_i = 1.65$ and $f_o = 6.00$ and that mean temperature is 40°F. This latter item is used in determining the value of a for air space. Value of k for brick is found in Table 2. Use Fig. 101. *Ans.* $U = 0.175$

7. Assume a 13-inch brick wall having 1 inch of plaster on the inside surface. Calculate the value of U. Hint: Use Table 2 to find k values for brick and plaster. Use Fig. 101 to find values of f and f_o, assuming 15 miles per hour wind as is generally assumed when not definitely given. *Ans.* $U = 0.280$

8. Assume a wall composed of 4 inches of face brick, sheathing, studs, a 1-inch corkboard, and $\frac{1}{2}$ inch of plaster. The air space is between the 2×4 studs. Assume wind at 15 miles per hour. Calculate value of U for such a wall. *Ans.* $U = 0.139$

9. Assume the same wall as in Problem 8 except that mineral wool has been put between the studs to fill up the space entirely. Calculate U. No answer is given, but the U value should be less than in Problem 8.

10. Assume that the wall of Problem 8 has ordinary lath (wood) and plaster in place of cork and plaster; otherwise wall is the same as in Problem 8. Calculate U.

Resistance Method of Calculating U Values. Prior to this point we have learned to calculate the value of U by the use of such formulas as (2) and (7), or by using tables such as Table 12 for pitched roofs and Table 5 for common types of outside walls. It is understood that, in Table 5 for example, the U value of .25 (for uninsulated frame walls) was determined by the use of such formulas as (2) to

4. What will be the infiltration through air-dried end and side-matched sheathing for wind at 15 miles per hour?

Ans. 50 c.f.h. per square foot of wall

5. Using an infiltration figure of 59.3 cubic feet per foot of crack per hour, what will be the heat requirement in a building with total crack (all windows and doors) of 180 feet, if the wind velocity is 15 miles per hour, the outside temperature 0°F., and the inside temperature 70°F. Use the method of solution where half the amount of crack is used and formula (12). *Ans.* 6724.6 B.t.u.

6. A solid 12-inch common brick wall is finished on the inside with $\frac{1}{2}$-inch insulation plaster base, and $\frac{1}{2}$ inch of plaster; the plaster base is furred 1 inch from the brick; k for insulating material is .34. Calculate the over-all coefficient U. Assume $f_i=1.65$ and $f_o=6.00$ and that mean temperature is 40°F. This latter item is used in determining the value of a for air space. Value of k for brick is found in Table 2. Use Fig. 101. *Ans.* $U=0.175$

7. Assume a 13-inch brick wall having 1 inch of plaster on the inside surface. Calculate the value of U. Hint: Use Table 2 to find k values for brick and plaster. Use Fig. 101 to find values of f and f_o, assuming 15 miles per hour wind as is generally assumed when not definitely given. *Ans.* $U=0.280$

8. Assume a wall composed of 4 inches of face brick, sheathing, studs, a 1-inch corkboard, and $\frac{1}{2}$ inch of plaster. The air space is between the 2×4 studs. Assume wind at 15 miles per hour. Calculate value of U for such a wall. *Ans.* $U=0.139$

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